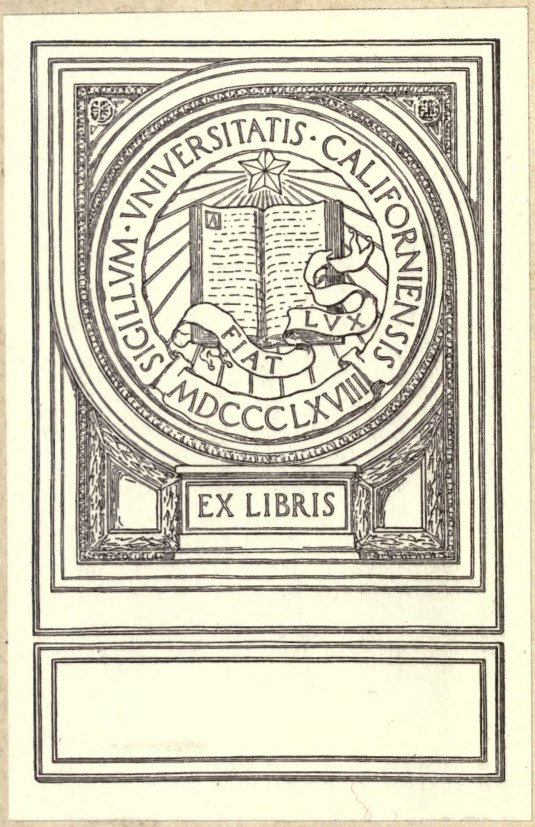
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A New Light.

Considerable attention is now being given in Paris to a new lamp, the invention of Messrs. B. Delachanal and A. Mermet, and intended for photographic and other purposes where a brilliant light is required.

The media employed are carbon sulphide and binoxide of nitrogen. Ignition of binoxide of nitrogen containing vapor of carbon sulphide produces a brilliant flame of a violet blue tint, peculiarly rich in chemical rays. The carbon sulphide lamp by which this flame is produced continuously is constructed simply of a flask with two tubulures, the vessel having about 30·5 cubic inches capacity. The flask is filled with spongy fragments of coke, or, better, of dried pumice, which imbibes the carbon sulphide. Through the central tubulure passes a tube to within a short distance of the bottom; in the other mouth or tubulure is fixed a tube of larger diameter, about 7·85 inches in length. The latter tube is of glass or metal, and contains an arrangement acting as a safety valve as well as impeding return of the gas and preventing explosion. Binoxide of nitrogen is passed by this tube into the flask, and the gaseous mixture is conducted by a caoutchouc tube to a kind of Bunsen burner, from which has been removed the air port and the cone regulating the supply of gas. The binoxide of nitrogen is produced by a St. Claire Deville apparatus; but instead of decomposing nitric acid by copper, which would be too expensive, a mixture of nitric and sulphuric acid is caused to act upon iron.

The flame, which is about 10 inches in hight, possesses high photogenic properties, and is much superior to the light obtained from the magnesium ribbon. The apparatus is nearly as portable, the mixed acid being contained in one vessel which communicates by a tube with a vessel containing fragments of iron. Supply is regulated by a cock. The flame is constant, unlike that of the electric light, and is not subject to spontaneous extinctions like the magnesium lamp. Photographs of human subjects are obtained in a less exposure than fourteen seconds. Photometric tests show (flame for flame, per measure) about twice the power of the oxyhydrogen light.

The inventors are studying the question of development of the green coloring matter of plants by means of this light. The experiments are being made in M. Dumas' laboratory at the Central School of Paris, and the result will shortly be made public.

CHEMICAL AND PHARMACEUTICAL MANIPULATIONS:

A MANUAL OF THE

MECHANICAL AND CHEMICO-MECHANICAL OPERATIONS

OF THE

LABORATORY.

FOR THE USE OF

CHEMISTS, DRUGGISTS, MANUFACTURERS,
TEACHERS, AND STUDENTS.

Second and Enlarged Edition.

BY

CAMPBELL MORFIT,

PROFESSOR OF ANALYTIC AND APPLIED CHEMISTRY IN THE UNIVERSITY OF MARYLAND,

AND

CLARENCE MORFIT,

ASSISTANT MELTER AND REFINER IN UNITED STATES ASSAY OFFICE.

WITH

FIVE HUNDRED AND THIRTY-SEVEN ILLUSTRATIONS.

PHILADELPHIA:
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TO

JOHN HENRY ALEXANDER,

ETC. ETC. ETC.;

IN APPRECIATION OF

HIS HIGH MORAL WORTH

AND

GREAT SCIENTIFIC ATTAINMENTS.

PREFACE.

To realize for Chemistry its true character of a science—to render it "a system illustrated and proved by experiment," there is an indispensable need of proficiency in those manual operations of the laboratory, by means of which chemical changes are induced, observed, and estimated. This accomplishment in manipulation—this expertness in handling and adjusting implements, it is true, depends upon time and practice; but although the student may not become an adept in the art solely from written instructions, yet much may be thus taught which will lighten his labors, and smooth the way to the acquisition of skill and accuracy.

Such is the object of the present work; and it has been made to comprise practical lessons upon the mechanical and chemico-mechanical business of the chemist, in reference both to the exact detail of analytic research, and the more extended processes of pharmaceutical science. Explanatory drawings of important forms of apparatus, too, have been profusely employed to give greater intelligibility to the text; and while the authors have drawn largely from their own personal experience, they have not neglected to make available all the useful information that was to be derived from other sources.

In this second and enlarged edition, there are many improvements upon the original work. The old matter has been emended, and much that is novel and valuable added; so that in its present form it embraces full and fresh teachings, adapted to the requirements of the uninitiated, as well as of the more advanced student.

C. M.

University of Maryland, Baltimore,
October 15, 1856.

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NH
$C_{28}H_{18}O_4$
$C_{10}H_5O_5$
$C_{15}H_8O_6$
O_7
$H_{17}O_{28}$
$C_{68}H_{66}O_{58}$

CHEMICAL AND PHARMACEUTICAL MANIPULATIONS.

CHAPTER I.

THE LABORATORY.

THE Laboratory is emphatically the workshop of the chemical operative; and chemical manipulation may be termed the practice of the science. A convenient arrangement of the first is no less desirable, for the success of operations, than a proficiency and skill in the latter are indispensable. New facts in science are mainly developed by experiment; and as chemistry is a purely experimental science, in every course of research,—as well in the most ordinary experiments as in the more delicate manipulations of analysis,—the surest basis of exact deductions is a skilful manipulation coupled with correct reasoning. This exemplification, by the hands, of the conceptions of the mind, is, therefore, an art of the highest importance in the study of chemistry.

The laboratory should be appropriately fitted, and arranged with a view to the ready prosecution of chemical investigation in all its several branches; and being the place where most of the operator's time is so profitably and pleasantly employed, no little regard, in its appointments, should also be given to personal comfort and convenience.

The apparatus must be selected with careful discrimination, so that the stock may consist, chiefly, of such pieces as admit of being adapted to the greatest variety of uses; and it will prove, ultimately, most economical to prefer those of the best materials and workmanship, though their first cost may be a little higher than that of inferior and less durable articles. Ample facilities, to this end, are presented by the extensive assortments of establishments whose speciality is the sale of chemical wares and

pure chemicals. They are now to be found in all our principal cities and towns, having risen during the last few years in obedience to the requirements of a prevailing taste for chemical pursuits. The implements which they offer, being skilfully constructed upon correct principles, promote the spirit and progress of experiment and facilitate a promptness and accuracy of results which might not be obtainable by less favorable means, except at a large expenditure of time and patience. Moreover, a familiarity with the use of good tools begets habits of precision which soon render the operator an adept in manipulation, and enable him to meet the exigencies of any new case by the suggestions of his experience and genius.

It is true that the dealers' exorbitant prices for apparatus are unreasonably high, and in a measure restrict the study of chemistry; but this imposture will be regulated by competition, as time increases the demand; for the original manufacturing cost is only a small moiety of the retail charge. Even at present prices, it is perhaps more judicious to draw supplies from such sources, for there is very little satisfaction and much loss of time that might be more profitably applied, in the employment of crude contrivances. In discouraging "*home manufactures*" in this connection, therefore, we cannot incur the reproach of extravagance, as our advice is based upon personal experience, and intended to protect the interest of the student.

In developing the plan for a Laboratory, we shall make our suggestions consistent with true economy; and while presenting a design, complete in all its details, will accompany it with such incidental instruction, as will render it capable of being modified according to the means of the operator or the purposes for which it may be intended,—whether as a Laboratory for public instruction or for private research.

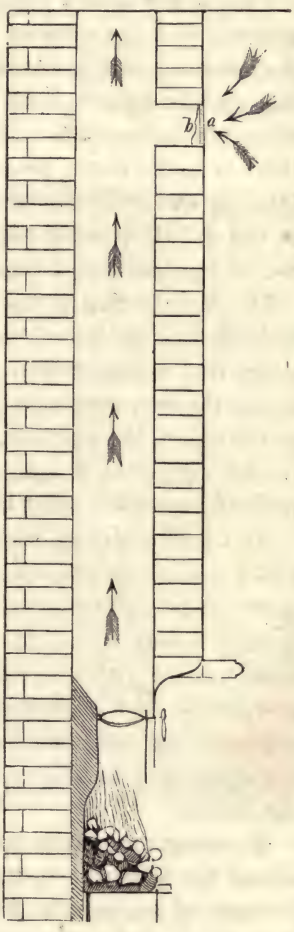
Health and comfort demand free light, regular warmth, and ample ventilation in all the apartments of a Laboratory. Light should be admitted through side windows, as they afford the greatest advantage for examining the action of reagents, particularly in those instances of delicate testing which result only in light flocculæ, faint cloudiness, slight change of color, or other behavior requiring nice scrutiny. By elongating the sash to nearly the whole height of the ceiling, the solar rays may be

brought under management when their aid is required in certain operations.

The sash should be hung with counterpoise weights, so as to give facility in raising or lowering them for the admission of air or other purposes.

Skylights are objectionable on account of their liability to frequent damage by storm and accident. They moreover present receptacles for dust and cobwebs.

Fig. 1.



The warming of the apartments may be best accomplished by means of Tasker's or other self-regulating water-furnace (*Journal Frank. Instit.* xxix, 417). The heat is radiated directly from the surface of iron pipes, distributed throughout the building and connecting with the generator in the cellar, which should supply them with a continuous current of steam.

This mode of heating combines economy with efficiency and is promotive of health, comfort, convenience, and safety from accident by fire; as it produces none of the usual disagreeability of dust and irregular temperature incident to "hot-air furnaces" and open fires.

As the internal atmosphere of the Laboratory is being constantly vitiated by noxious emanations from substances under process, as well as by respiration, efficient means must be adopted for displacing the foul air by introducing, simultaneously, pure fresh air in such a manner as to prevent discomfort from cold draughts. The tendency of the foul air, even when not specifically lighter than the surrounding air, is to ascend, owing to its being rarefied by the heat of the Laboratory, and therefore it may be readily made

to pass from the apartment through a panel of coarse wire grating (Fig. 1, *a*) placed in the wall of the chimney flue, near the ceiling. This panel should be twelve inches broad and nine inches high for a room of forty feet square, and proportionably smaller for one of lesser dimensions; and to prevent the entrance of smoke in gusty weather, there should be affixed to the inside a hinged flap (*b*) made of very fine wire gauze. The draught action of the warm flue carries away the unwholesome air, as shown by the arrows; and the pure air entering, to supply its place, through the many crevices in the doors and windows, and about the building, quickly diffuses itself and thus becomes warm without creating any perceptible cold currents. Even in summer, or when there is no fire on the hearth to dilate the air in the flue, the wind blowing across the top of the chimney produces a partial vacuum at the mouth, towards which the upper air of the room will be moved by the upward pressure of the denser lower strata.

Dr. Murray uses a funnel-mouthed tube instead of a grating, and conveys the tube through the ceiling into a chimney, where there is a constant fire. To provide against the entrance of smoke through any imperfection of draught, the pipe is continued to the top of the chimney. The warmth of the chimney rarefies the air within the pipe, and ventilation is effected, upon the principle above-mentioned.

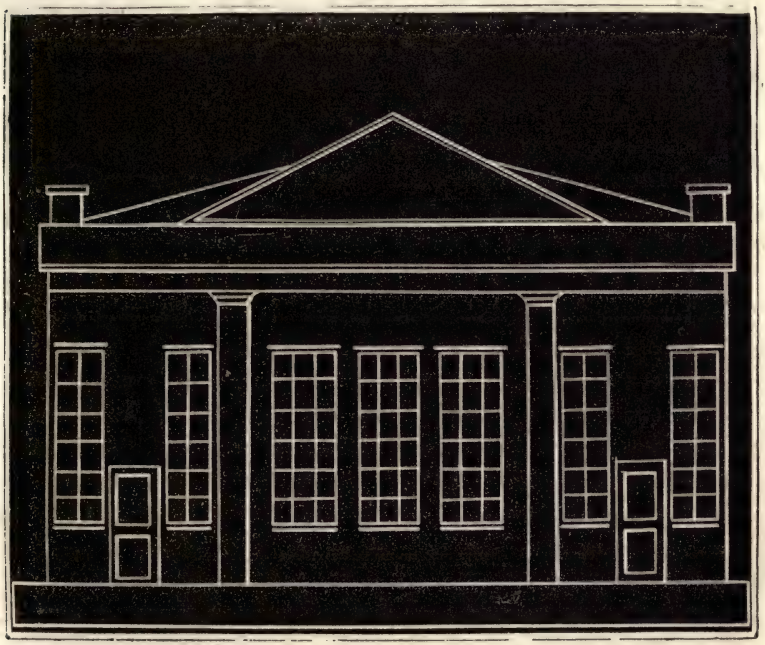
The laboratory apartment should be sufficiently spacious to afford a separate place for each of the requisite utensils. Too much crowding of apparatus is apt to produce damage, and is, besides, inconvenient; for nowhere than in a Laboratory is there more necessity of a strict observance of the rule, "*a place for everything, and everything in its place.*" Hunting up mislaid apparatus consumes time, and the delay thus occasioned, in many instances, may be the means of serious detriment to important operations.

A roomy apartment on the first floor of a building is best suited for laboratory purposes. The first floor is recommended, because of its greater convenience for the admission of water, fuel, &c., and for the removal of the slops, sweepings, &c. It should be partitioned off into four several apartments, the middle or larger of which should be the main operating room, whilst the smaller at either of its sides are used, the one as an office, the

other as the furnace room, and the third for the balances. This arrangement protects the middle room from the dirt and dust of the coarser furnace operations, and the balances from the influence of corrosive vapors; and what is equally indispensable, by means of the office as a reception room, presents a bar to all unwelcome intrusion from without.

As, in some instances, it may be convenient to construct a building especially for a laboratory, we present the plan of a properly furnished one, such as might be completed for a very moderate outlay. It is of coarse brick, and rough-cast with mastic, which, becoming indurated in a short time, serves as a

Fig. 2.



perfect protection to the walls against all dampness, and imparts a stone-like appearance to the building. A very good mastic may be made by *oven-drying* a mixture of the following powders, and then working it, in the usual manner of mortar, with one-seventh of its total weight of linseed-oil:—14 volumes of silicious sand; 14 volumes of powdered limestone; 1-14 in weight of litharge,—that is, one-fourteenth of the joint weight of the

sand and stone. The surfaces, which are to be covered with this mastic, must first be washed over with linseed-oil containing five to ten per cent. of rosin-oil. The linseed-oil used in the mixture might also contain a portion of rosin-oil, which, without detracting from its quality, will lessen the cost of the mastic.

Figure 2 gives the front view of the building. Though regard is had more particularly to economy and convenience in its construction and arrangement, yet there is sufficient reservation of architectural symmetry to impart a neat and becoming appearance. In the arrangement of the ground plan, we observe the same positions as are recommended in the adaptation of a room to laboratory purposes, so that our suggestions are equally applicable to either case. The whole front of the building is forty feet. Its depth is twenty-four feet. The ceiling should be high, say from eighteen to twenty feet. The roof is square, slightly inclined, and of metal. There are two entrances only, one in the left wing or furnace room, for the ingress and egress of material and refuse, and the other in the office or anteroom. The centre or operating apartments are thus preserved from all inconvenience of dirt, dust, or intrusion. There are two chimneys, that in the office being for the stove-pipe, when a stove is to be used for warming, and the other in the left wing for the flues of the furnaces, still, &c. The windows should extend nearly to the top of the ceiling. In the preceding figure, they are twelve feet by two feet eight inches, in the centre apartment, and twelve feet by two feet in the wings. The glass panes of the former number eighteen, those of the latter twelve. The doors have a width of two feet nine inches, and height of seven feet; and each should be furnished with a spring. Oiled linen makes an excellent curtain for protection against the summer sun, without too much obstruction of the light. It should be hung on Putnam's

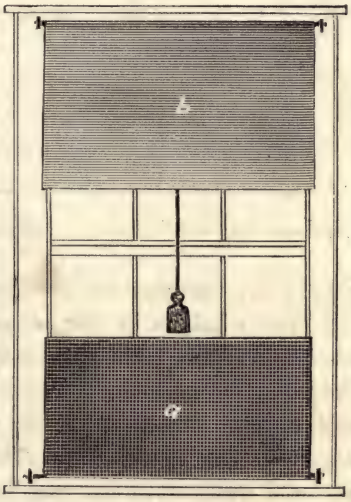
Fig. 3.

"balance spring-rollers"—Fig. 3—in which the use of cords is dispensed with, the curtain being raised, lowered, or held in a fixed position by means of a counterpoise weight.

Curtains thus hung were exhibited at the last Annual Fair

of the Maryland Institute, by Baker and Cushman, of Baltimore. The roller is a hollow tin cylinder, 1½ inches diameter, and revolving upon a metal rod, which is wrapped with a spiral spring of brass wire; and the combination is so adjusted, that when the weight, disguised as a tassel, receives a slight upward motion from the hand, the wire spring recoils, and the curtain *b*, Fig. 4, fastened in a groove, is wound up by the roller to any desired height. The roller and curtain are suspended by brackets at the top of the window; and the act of drawing down the curtain turns the cylinder and winds up the spring. This arrangement admits also of the application of a self-acting dust-bar *a*, which consists of mosquito-netting so fixed to the lower half of the sash, that when the latter is raised it draws up the former to take its place. This apparatus will be found very convenient in windy and dusty weather, when it is desirable to have free access for air to the apartment without endangering the comfort of the occupant or the safety of the apparatus, &c. The roller is equally advantageous for hanging diagrams as curtains.

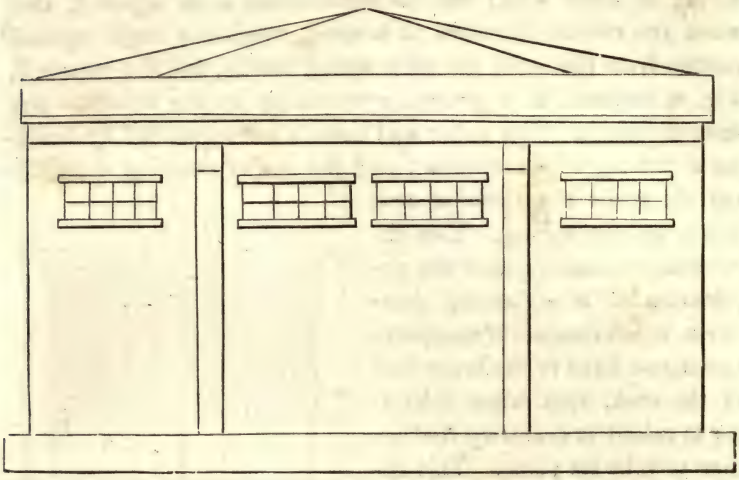
Fig. 4.



The top moulding of the building is of wood, plain and painted, and the pillars represented in the cut, are only projections of the brickwork to ornament the front of the building. It is seen by Fig. 5, which represents a back view of the laboratory, that the rear windows differ in form and position from those in the front. The reasons will be obvious on explanation. For the convenient arrangement of apparatus, it is necessary to have as much wall-room, interiorly, as possible; and as the ample windows in the front will furnish most of the requisite light, the rear windows, which are of sufficient extent to supply the remainder, are elevated so as not to interfere with the tables, shelving, and fixtures, resting against the wall beneath. These windows should

be hung upon metal pivots, so that they may be readily opened or shut at will. The front window-sash, for reasons before given,

Fig. 5.



should be counterpoised by balance weights. The dimensions of the rear windows in the wings are six by three feet, and the number of glass panes in each window are eight. The side light is also admitted through three elevated windows in each end of the building. Their size is six by three feet, with eight panes of glass each. The centre apartment has also two elevated windows in the rear, but their width is one foot greater than those in the wings. All of these elevated windows should be hung upon metal pivots. This elevation of windows in these apartments is also with a view to the economy of wall space within. The basement, which, by a little expense, may be appropriately fitted for the purpose, serves as a receptacle for fuel, bricks, charcoal, tile, rough materials, and cumbersome apparatus not in constant use. The best color for the woodwork is white —preferably, of pure zinc white; and the walls and partitions of lath and plaster should be smooth, so that the laboratory may be as free as possible from loopholes for the accumulation of dust. A stiff brush mat and scraper should always be furnished for each entrance. If the means of the owner will permit the expense, it would add much to the appearance of his place to sur-

round it with a garden plat. Thus, in improving the beauty of the spot, he would be providing the means of pursuing investigation practically, to a limited extent, in agricultural chemistry.

Plate 2 represents a ground plan of an experimental and analytical laboratory, either as especially constructed for the purpose, or from any room of adequate dimensions. The main divisions of the apartment, as before said, are three, the fourth in the plan being only a subdivision. The two wings A and B, of equal size, are 10·3 by 22·6 feet in the clear. That on the right should be used as the office and balance room, the left wing being occupied exclusively for furnace and grosser operations, leaving the centre or operating room C, occupying the whole residual space of the floor, for the nicer manipulations.

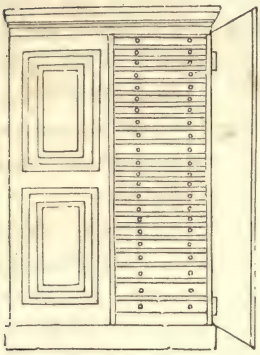
The Office.—This being the studio of the operative should contain both the library and the mineralogical, geological, and technical cabinets. These latter, not, however, necessarily extensive, are very convenient for reference, as instances frequently occur, in the course of practice, requiring a comparison of specimens. The two front windows, together with the two elevated windows at the outer side, serve for the free admission of light. This being also used as the reception room, there is an entrance door, between the two windows, of dimensions equal to those of the door in the furnace room. The floor should be carpeted, or, preferably, covered with oil-cloth, which is more durable, and readily cleansed. The bare spots on the walls, as well as the upper parts of the blank spaces between the doors and windows, may be furnished with brackets for the busts of distinguished chemists, or hooks upon which to hang their framed portraits; and the lower part beneath the windows may be reserved for chairs *k*. The blank space *j* over the door leading into the operating room can be occupied with a cheap Yankee clock, a very requisite and convenient piece of furniture in a laboratory.

It is necessary to be minute in describing the arrangement, for, unless there is some system, there can be no economy of space, and hence much confusion. In the centre of the wing is the chimney *a*, and immediately opposite, in near juxtaposition, the hot-water stove *b* which warms the apartment.

Against the off wall, and to the left of the stove, is the mineral case. There should be at least two of these, and the second may

occupy the vacancy in the wall immediately opposite. The positions of these cases are represented in Plate 2 by the letters *c* and *d*. Fig. 6 below gives an idea of their form and construction. They are, in fact, nothing more than mere wardrobes, with the shelves and drawers substituted by sliding trays. They can be of some cheap wood, and painted. The sliding trays are much more convenient than drawers, and present less liability of damage to their contents, as they admit of easier handling, it being frequently necessary to draw them out to examine their contents. The specimens which they are to preserve, secure from dust and unwarrantable handling, should be separately encased in shallow pasteboard boxes, each bearing the name and locality of the mineral. The minerals should be so classified that only one species may be assigned to a tray, which should be labelled on its face accordingly. The trays may be of 3 to 4 inches depth, with intervening spaces of an inch or less, and the number of them in proportion to the dimensions of the case, which, in height, should not exceed eight feet.

Fig. 6.

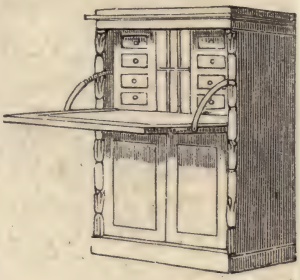


There ought to be, properly, another case of smaller dimensions, for the reception of such minerals and specimens as may have been subjected to analysis. They should be labelled to correspond with the memoranda of them noted in the record book of the laboratory, as instances frequently arise of a necessity of future reference, and hence the policy of this arrangement.

The writing-desk, which is the main piece of furniture of this room, should stand against the back wall of the office, as shown in Plate 2 by letter *e*. Its form and construction are represented by Fig. 7. It is made to occupy as little room as possible, and yet at the same time to possess all the requisite conveniences of an escritoir. The small drawers and cuddies are concealed by a cover or writing flap, which is supported by metal quadrants, and goes up perpendicularly, forming, when closed, a part of the front.

The drawers are well adapted for stationery, and the cells for the manuscript papers, notes, letters, &c. The doors in the lower part cover a series of shelves, which may be used as receptacles for accumulating papers, which should be filed away in bundles, and indorsed with memoranda of their contents. The sliding flap, as well as the doors beneath, are fitted with locks; and the desk, when closed, has the appearance of a handsome secretary;—and thus we have the means of preserving its privacy during our temporary absence from the office. To the right and left of the desk, the blank spaces of the side and end walls must be appropriated to shelving for the library. It is better to have them elevated, rather than resting immediately upon the floor. The pedestals may be two feet, and the shelving above, six feet high. The pedestals, or base, should be broader than the shelving above, and may be fitted with deep slats for the reception of charts, diagrams, pamphlets, &c. The upper shelves are to be reserved exclusively for books; and to protect them from the dust, must be enclosed with curtains, hung as before directed. The position of this shelving is shown in Plate 2 by the letters *f f f*.

Fig. 7.

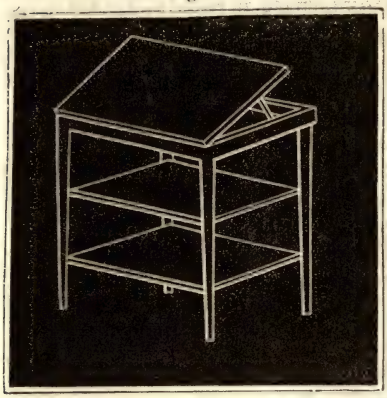


The vacant spaces upon the wall above the shelving and cases may be very appropriately used for hanging maps, mounted charts, diagrams, &c., selecting such as are of frequent use for reference.

The table g_1 standing midway between the centre and front of the room, is one of the greatest conveniences of the apartment. It combines in its construction the requisites of a drawing-table and chest, a centre-table, and map-stand. Walnut is the most preferable material for this piece of furniture, which should be strongly made, and firmly fastened to the floor by iron clamps and screws. Its superficial dimensions are 4 by 2 feet, and its height 38 inches. The top, of an inch thickness, is a rising flap, and covers a shallow tray, or receptacle for paper, drawing materials, and unfinished drafts. The prop-stick catches in a graduated ratchet, indented in the flap, and permits the raising of

the top to any desired inclination, and renders it available as a writing or drawing-desk. By lowering the top, so as to make a level table, a flat support is formed for the examination of folios, large drafts, and charts, which require a broad spread and careful usage. The shelving beneath is very convenient for the preservation of this portion of the library, for being of adequate dimensions, the drawings need not, necessarily, be crumpled, in being placed away.

Fig. 8.



A small step-ladder, for convenience in reaching the top shelves of the mineral and book-cases, is very necessary in the office, as well also in the other apartments of the laboratory.

CHAPTER II.

THE BALANCE-ROOM.

The small room D in the rear of the office, and from which it has been partitioned, has a width of eight feet, and is to be exclusively used as the balance-room, and store for metallic apparatus. They are thus housed in a close, dry apartment, to preserve them from dampness and injury, and from deleterious exhalations to which they would be exposed in the working-room during the progress of operations. The two balances occupy separate places, and should rest upon solid shelves, firmly fastened to brackets set into the wall. These shelves stand immediately against the outer side wall, as shown at letters *g g* in Plate 2. The remaining wall space is fitted with curtained shelves, or, preferably, glass cases, for the reception of the metallic and other finer apparatus which require care in their preservation. The entrances *h h* from the office into the main room

are closed with tightly fitting doors, which may be fastened by dead-latches, and should always be kept closed by means of a spring. Their dimensions are 2 feet 10 inches in width, and 7 feet height.

This apartment is also to be kept warm by means of a water-stove placed in the corner or other convenient position.

CHAPTER III.

THE FURNACE-ROOM.

PASSING over the operating-room for the present, we proceed to describe the furnace-room B, which occupies the left wing of the building to the whole depth, without any subdivision for other purposes. Its width is ten feet three inches. In this room are performed all the operations requiring the use of furnaces, stills, and steam, and in their progress generating deleterious fumes, dust, or dirt. It is therefore necessary for the comfort of the chemist, and the preservation of the apparatus, to keep the side door *i*, (7 feet high, and 2·10 wide,) leading into the main apartment, constantly closed. The front of this wing is, as to windows, identical with that of the office. The free admission of light, which is effected by means of the two long front and three elevated side windows, is as requisite in this as in the operating-room. The chimney of this apartment occupies the centre of the outer wall, and receives the main flue, furnishing draft to the main furnace and two lateral branches. Of these two branch flues, both of which have circular openings, with movable tin stopples, one is for the reception of the smoke-pipe of the still furnace E, and the other for that of the steam generator F; or, when not in use otherwise, for the portable blast, and other furnaces. These flues are fitted with dampers to regulate the draught; and the circular opening, when not occupied with apparatus, or as vent-holes for the dispersion of noxious vapors, should be kept covered, so as to preserve unimpaired the draught of the main furnace.

The Furnace.—The furnace G, which is in constant use for

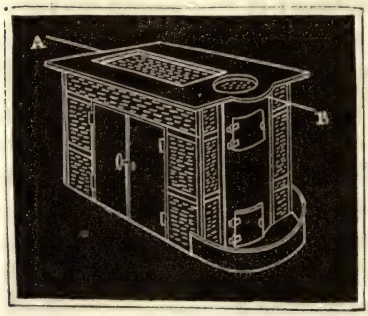
the ordinary operations of the laboratory, occupies the centre of the outer wall. One of simple construction is described by Faraday, to whom we are indebted for drawings, &c.

"Being in constant requisition as a table, it should be about 34 or 35 inches in height. The brickwork should measure 36 by 20 inches, and the iron plate, including sand-baths, 40 by 28 inches. A warm air chamber may be built in the walls beneath the flue. Projecting spikes should be fastened into one or two sides of this chamber, to hold a temporary shelf when required.

"Precipitates, filters, and other moist substances put into such a chamber, are readily and safely dried. The hot air causes evaporation of the water, whilst the current removes the rising vapor. The chamber is very useful in effecting the slow evaporation of liquids, and also for hot filtrations, when the entering current of air is of a temperature sufficient for the purpose.

"The principal part of this furnace is necessarily of brickwork, only the top plate with the baths and the front, being of iron. The front is a curved iron plate, having two apertures closed by iron doors, one belonging to the fire-place, and the other to the ash-pit. It is 34 inches high, and 14 inches wide. The ash-hole door moves over the flooring beneath; the bottom of the fire-place door is 22 inches from the ground, and the door itself is 8½ inches by 7. This front is guarded within at the part which encloses the fire by a strong cast-iron plate, having an opening through it corresponding to the door of the fire-place. It has clamps attached to it, which, when the furnace is built up, are enclosed in the brickwork."

Fig. 9.



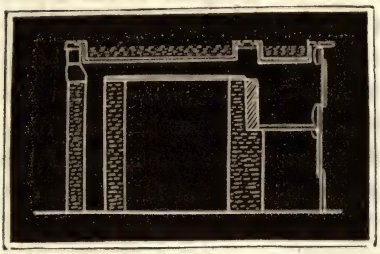
In the setting or building of the furnace, two lateral brick walls are raised on each side the front plate, and a back wall at such a distance from it as to leave space for the ash-hole and fire-place; these walls are lined with Welsh lumps, where they form the fire-chamber; two iron bars are inserted in the course of the work to support the loose grate bars in the

usual manner, the grate being raised 19 inches from the ground. The side walls are continued until of the height of the front, and are carried backward from the front in two parallel lines, so as to afford support for the iron plate which is to cover the whole. The back wall of the fire-place is not raised so high as the side walls by six inches and a half, the interval which is left between it and the bottom of the sand-bath, being the commencement of the flue or throat of the furnace. In this way the fire-place, which is fourteen inches from back to front, and nine inches wide, is formed, and also the two sides of the portion of horizontal flue which belongs to the furnace, and is intended to heat the larger sand-bath. The bottom of this part of the flue may be made of brickwork, resting upon bearers laid on the two side walls, or it may be a plate of cast iron resting upon a ledge of the brickwork on each side, and on the top of the wall, which forms the back of the fire-place. When such an arrangement is adopted, the plate must not be built into the brickwork, but suffered to lie on the ledges, which are to be made flat and true for the purpose; for, if attached to the walls, it will, by alternate expansion and contraction, disturb and throw them down. The ends of the side walls, forming as it were the back of the furnace, may be finished either by being carried to the wall against which the furnace is built, or enclosed by a piece of connecting brickwork, to make the whole square and complete; or a warm air cupboard may be built in the cavity beneath the flue, and the door made to occupy the opening between the walls. Occasionally the flue may be required to descend there, and pass some distance under ground. These points should be arranged and prepared before the plate constituting the top of the furnace is put on to the brickwork, so that when the plate with its sand-baths are in their places, they may complete the portion of horizontal flue by forming its upper side.

The size of this plate is the first thing to be considered, and having been determined upon, from a consideration of the situation to be occupied by the furnace, and the places of the sand-baths also having been arranged, the brickwork must then be carried up, so as to correspond with these determinations, and with the plate itself, which in the meantime is to be cast. The sand-baths and the plate are to be formed in separate pieces.

The bath over the fire is best of a circular form, and of such diameter that, when lifted out of its place, it may leave an aperture in the plate equal in width to the upper part of the fire-place beneath; so that a still, or cast-iron pot, or a set of rings, may be put into its place over the fire. The other sand-bath must be of such a form as to correspond with the shape and size of the flue beneath. These vessels are to be of cast iron, about three-tenths of an inch thick; their depth is to be two inches and a half or three inches, and they are to be cast with flanches, so as to rest in the corresponding depressions of the plate, that the level of the junctions may be uniform. This will be understood from the accompanying section of the furnace, given through the line A B of the view. It is essential that these sand-baths be of such dimensions as to fit very loosely into the apertures in the plate, when cold, a space of the eighth of an inch or more being left all round them, as shown in the section, otherwise, when heated, they will expand so much as entirely to fill the apertures, and even break the plate. The plate itself should be half an inch thick.

Fig. 10.



When the plate and its sand-baths are prepared, and the brickwork is ready, the furnace is finished by laying the plate on the brickwork, with a bed of mortar intervening. If the walls are thin, or any peculiarity in their arrangement occasions weakness, they should be bound together, within by cranks built into the work, and without by iron bands. The alternate changes of temperature from high to low, and low to high, to which the furnace is constantly subject, renders it liable to mechanical injury, in a degree much surpassing that which would occur to a similar piece of brickwork, always retained nearly at one temperature." The square space enclosed by the fire-place and flues may be converted into an excellent drying or warm air chamber if desired.

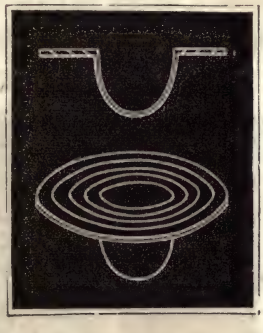
Cast iron is the best material for these baths, for, though liable to be cracked when first heated, by their unequal expansion in

different parts, they do not warp and assume the irregular and inconvenient shapes that wrought iron acquires under similar circumstances.

"These baths should have washed sea-sand put into them; it is heavy, and occasions no dust when moved, whilst, on the contrary, unwashed and bad sand contains much dirt, and occasions great injury in experimenting. A piece of straightened iron hoop, about twelve inches in length, should lie on the furnace, as an accompaniment to the baths, being a sort of coarse spatula with which to move away the sand.

"The circular sand-bath is frequently replaced by a set of concentric iron rings, or a cast-iron pot. The rings are convenient for leaving an aperture over the fire of larger or smaller dimension, according as a smaller or larger number are used at once; and being bevelled at the edges, fit accurately into each other, without any risk of becoming fixed by expansion. The external one, like the sand-baths, should be made smaller than the depression in the furnace plate in which it rests. The iron pots are of various sizes, and are adapted to the furnace by means of the rings; a red heat is easily obtained in them for sublimation."

Fig. 11.



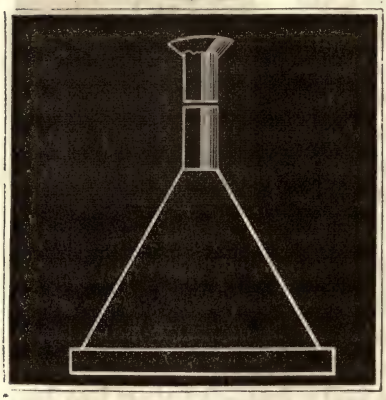
In many instances, where economy is of prime importance, the foregoing sand-bath may be replaced by an ordinary cylinder stove, the pipe of which leading into a four-sided sheet iron box, divided into flues by partitions, imparts its heat in transitu to the chimney. The top of this box, when covered with sand, forms the sand-bath. That portion of its surface immediately over the first flue, is the hottest. The remote or cooler end, is best adapted for gradual digestions, evaporations, &c.; and so by these flues there is a means of graduating the temperature of the bath. The top of the stove itself being directly over the fire, makes an excellent bath for those operations requiring a higher temperature; and by adjusting an outer casing of tin plate to the circumference of the stove, a drying chamber may be formed.

The steam generator (Fig. 13) when used as a stove for heat-

ing the apartment, answers equally well to heat the bath, it being only necessary to conduct its smoke-pipe into the iron box instead of leading it directly into the chimney.

To prevent contamination of the atmosphere of the apartment, by admixture with the deleterious fumes evolved during the various operations of digestion, fusing, melting, heating, and evaporating in progress upon the sand-bath and in the furnaces, there should be firmly fastened to the ceiling and immediately over its surface, extending beyond its superficies some four inches all around, a sheet-iron hood, of form at the base corresponding with that of the top of the furnace. The barrel of this hood may pass either directly through the ceiling and roof into the atmosphere, or else be formed into an elbow, leading into the main flue of the chimney. In either case, the draft must be thorough, so as to afford a free egress of the fumes into the atmosphere without. It should also be immovably fixed by rod iron stretchers, and well payed over with zinc paint. The fixture is represented by Fig. 12. It should descend as near to the surface of the bath as convenience of manipulation will allow; and to prevent any accumulation of dirt in the interior, it should be frequently brushed out with a soft brush; and for protection to the vessels on the sand-bath, against falling particles, the top of the furnace should, during the operation, be covered with paper. It is advisable at all times, independently of the foregoing suggestion, to keep each vessel covered with plates or clean white paper, which, while protecting against dirt, offers no impediment to the processes of evaporation, digestion, &c. If the hood, instead of being fixed, is counterpoised, so as to admit of ready depression or elevation at will, it is a little more convenient; but that arrangement has the disadvantage of liability to accident, for a carelessness in fastening the suspension cords may create a very annoying da-

Fig. 12.

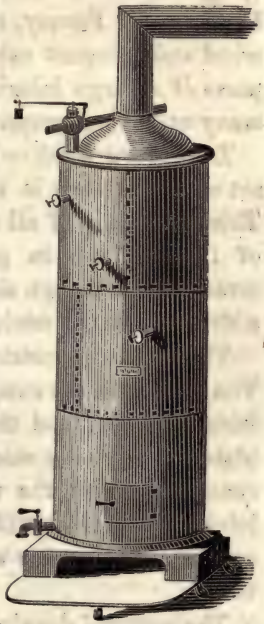


mage. Of course, this mode of hanging the hood can only be adopted where the barrel or pipe is straight, and leads directly through the roof; and then to protect the exit hole from the wear and tear consequent upon the abrasion of its circumference, it should be fitted with an earthenware cylinder; and furthermore, to prevent the entrance of rain through the slight openings, there should be a spreading flange around the protruding portion of the barrel of the hood, near the roof.

Furnace.—The air or wind furnace of a laboratory is generally a fixture made of refractory brickwork and iron; but the Universal Furnace and Barron's Blast Furnace, described in Chapter XI, are more convenient portable apparatus, which will serve for all the purposes of the laboratory.

The Steam Generator.—To the right of the furnace, at a convenient distance, is the portable steam generator F, with its smoke pipe leading into the circular opening of the lateral flue opposite. It has a stove-like form, is compact, requires no brickwork, and but very little fuel, and can be set up and removed at will, when it is desired to occupy the flue with other apparatus. The only fixtures requisite, in addition to the machine, are feed pipes to convey the water, and conduits for the passage of the steam. It is a most convenient apparatus for the laboratory, being alike handy for economically supplying hot water to all parts of the building, and for boiling substances, where the direct admission of steam is preferable; and also for heating the steam series in the range a little to its left. This mode of applying heat, having the great advantages of safety, convenience, and regularity, is absolutely requisite in many cases where the naked fire does not offer that uniformity of temperature which the alterability of certain substances under process renders necessary. Fig. 13 represents the apparatus. By means of coupling screws and flexible lead pipe, the steam may be carried to

Fig. 13.



any reasonable distance in any direction, thus affording great facility in many operations; as the loss by condensation in thus conveying it is inconsiderable. In very cold apartments, however, when the conduit pipe is of any great length, it may very properly be enveloped with woollen listing or other bad conducting materials. The lower cock in the figure connects with the feed pipe. The three smaller cocks above, and placed equidistant from each other, are try cocks, to ascertain the height of the water, by which its supply must be accordingly regulated. The steam conduits are coupled by a cock fitted to the top of the generator.

The door in the lower part is for the introduction of the coal into the fire hole.

For laboratories of public institutions, or for any laboratory which it is desirable should be complete in its arrangement, the better plan will be to combine the generator, sand-bath, and drying chamber in one and the same piece of apparatus. This is done to a certain extent in Beindaff's apparatus, which will hereafter be described; but that implement is only adapted to small operations. We have, therefore, aided by the practical skill of Matthew Y. Forney, engineer, of Baltimore, devised an economical and compact substitute, which is efficient for all the purposes of a large laboratory, and may, from its capacity for so many uses, very properly be called the

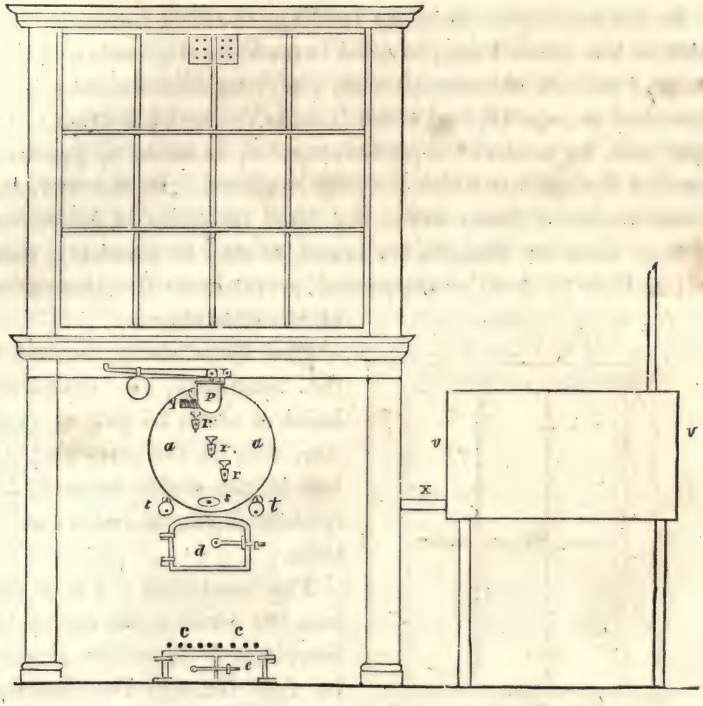
Laboratory Jack.—It consists wholly of metal, and may be set up like a stove in any position convenient to a chimney flue. This is a saving of all the expensive mason-work of other forms of furnaces now in general use for similar objects, and the arrangement, though simple, comprises all the requisites of such a structure in the minimum of space and over a single fire.

The apparatus consists of two parts, the frame and the boiler. The first, with the exception of the glass window, is cast in iron, from patterns; and the latter is made of strong wrought iron plates. It is very essential that all the workmanship shall be exact, for unless the various parts are closely adjusted at the joints, the machine will be wanting in that neatness of appearance which otherwise would render it an ornament to the apartment.

The annexed drawings show the apparatus upon a scale of one

twenty-fourth its actual size, Fig. 14 being a front view, Fig. 15 a side view, and Figs. 16 and 17 longitudinal and transverse sections.

Fig. 14.

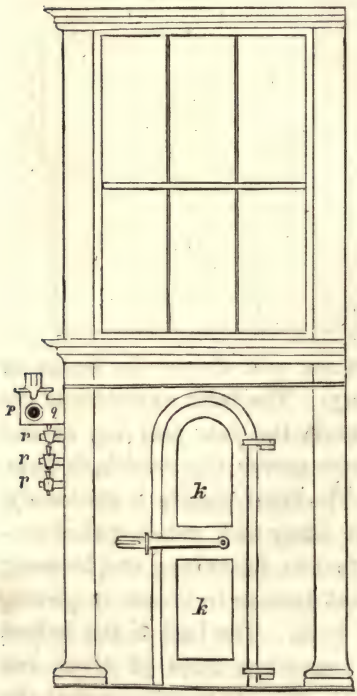


For convenience of illustration, we will divide the frame or stand into an upper and lower story. The front and sides of the upper story are formed of sash-work, the rear and top of stiff sheet iron plate; and this enclosure covers the sand-bath forming the top of the lower story. The front window is stationary, but each of those at the sides are hung with counterpoises concealed in the corner pillars; this facility for raising and lowering them being indispensable to prevent damage to vessels in placing them or removing them from the bath. The bath is also ledged around its circumference, with soap-stone slabs of about one inch thickness and six inches width, so as to provide against the breakage of glass or other fragile vessels, in case they should be, temporarily, placed there on being taken from the bath. The durability of that material, its resistance of the action of corro-

sive agents, and limited power of conducting heat, render it much more suitable for this purpose than metal. The four slabs forming the ledge are so fitted as to present a level and smooth surface, in order that the base of the sash may fit closely to it.

As the emanations from the vessels on the sand-bath are always more or less deleterious, provision is made for their uninterrupted passage into the chimney through a register like the one already described at page 19, and which is set at the top of the rear of the jack, and, by means of a pipe-connection, is made to penetrate into the flue against which the jack is placed. In this way, any accumulation of fumes within the glass enclosure is prevented; so that, when the windows are raised, as may be necessary, there will be little or none to escape and contaminate the atmosphere of the laboratory.

Fig. 15.



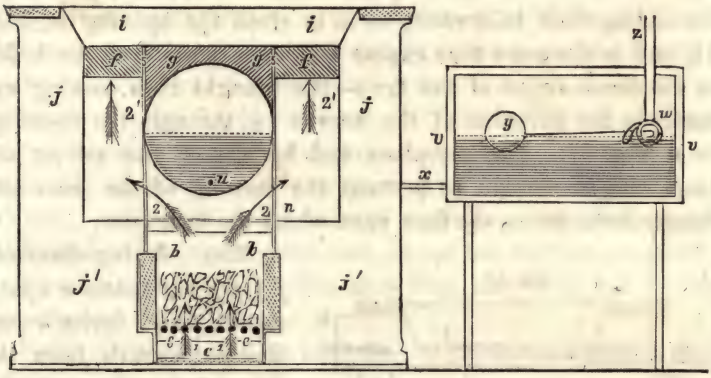
The lower story consists of the sand-bath, a cylindrical boiler of about 25 gallons' capacity, with its fire-place and ash-hole in the centre beneath, and spacious drying-chambers at the sides.

The sand-bath *i i* is a cast iron box forming the cap of the fire-place *b b*, which receives its fuel through the doorway *d*. The heating-chamber is so planned, that the draught entering at *e*, Fig. 14, follows the direction of arrows 1 1 until it reaches the extreme end of the boiler, where it divides to rise in two lateral currents, as shown by arrows 2, 2, 2′, 2′, Fig. 16, and then pass forward through the openings *f f* to the front of the boiler, where they turn into the flue *g g*. Fom this latter it continues back in the direction of the arrows 3 3, Fig. 17, to the flue *h* leading into the chimney. This winding course graduates the heat of the bath to

different degrees,—the hottest temperature being in that part where the draught first strikes the bottom plate, and the most moderate over the exit flue. The heat of the other portions varies according to proximity or remoteness in regard to these two extreme positions. This multiplicity of temperatures by means of one fire, and always ready for use, will be found a great convenience. A damper for regulating the fire is placed at 5 5, Fig. 17, where the two flues *f f* enter the flue *g g*.

The boiler *a a*, which, as before directed, should be made neatly and strong, is placed below the bottom and centre of the sand-bath, and extends the whole depth of the jack. On the front end is the safety-valve *p p*, with a side nozzle *q* for connecting the distillation and steam-pipe, as will be described directly. Immediately below it are the guage-cocks *r r r*, for determining the height of water in the boiler; and under these,

Fig. 16.



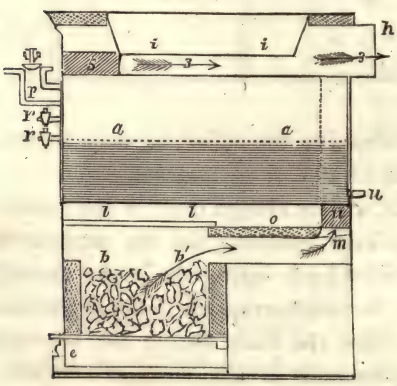
again, is the hand-hole *s* for cleaning the boiler, as may become necessary by the accumulation of deposited matters.

The boiler, from its position, will be always more or less heated by the fire beneath, which is kept constant, for the purpose of maintaining the heat of the sand-bath during the night as well as the day, so that there may be no interruption to the digestions and other processes in action upon the bath during the absence of the attendant. This circumstance is also made subservient, in the construction of the jack, to a very necessary provision, and that is a continuous supply of distilled and warm waters, and a

regular uninterrupted temperature in the adjacent drying-chambers at the sides. When the use of the boiler is to be restricted to these objects, the heat must be kept down; for which purpose, there is a sliding shelf *l l* in the fire-place. This, on being drawn forward, as shown in Fig. 17, turns the draught in the direction of the arrows 1 1, and thus intercepts the immediate action of the fire upon the boiler. The shelf is of cast iron; and has a grooved rim for holding in place a soap-stone lining, which is necessary to diminish the conducting power of the metal. As a further means of restricting the heat within the proper degree, there are openings *t t* for admitting cold air under the boiler; but as it will be necessary to use steam occasionally, they are fitted with covers for shutting off the current in such cases.

The heat obtained as above is sufficient to evaporate the water in the boiler and send it off in the form of vapor, to be condensed as distilled water; but, to convert it into steam, the whole force of the fire is requisite. This is applied by pushing the sliding-shelf backwards, so as to close the opening *m*, Fig. 17, and at the same time expose the lower portion of the boiler to the direct action of the fire;—the draught then passing upwards in the direction of the arrows *l o*, through the openings *m n*, Fig. 17. The fire-place and bottom of the ash-pit are lined with soap-stone, to prevent the burning of the sides and danger from fire to the floor upon which the jack rests.

Fig. 17.



The drying-chambers *j j j j* are spacious apartments, which derive a continuous warmth from the sides of the adjacent boiler and fire-place; and the temperature is of a degree most suitable for the drying operations of the laboratory. They are always ready for use; and to add to their convenience, the ends are cast with projections at proper intervals, for the support of iron shelves. All of these shelves are movable, and

some are bored with holes throughout their surface, so as to make the chamber available for large vessels and funnels, as well as for those of smaller dimensions. The doors *k k* afford access to the interior as may be necessary.

To carry out the design of making this apparatus self-managing as far as possible, the boiler is fed from a suitably adapted reservoir, Fig. 16, in proportion as it loses water by evaporation. The supplies are admitted through the opening *v*, and the pipe *x*, connecting with a wooden cistern *v v*, placed in any convenient corner of the apartment. This pipe may be, for the sake of protection and convenience, laid under the floor, but, in such case, it will be necessary to wrap it with several layers of woollen listing, or else to imbed it deeply in straw, to prevent freezing in cold weather. The level of the water in the reservoir is kept constantly in adjustment with that in the boiler, by means of the valve-cock *w*; and to regulate this cock, there is a hollow ball or float *g* of sheet-copper. As the level of the water in the reservoir falls, the float of course descends with it, and, in so doing, opens the cock for admission of water from the hydrant, to replace that which passes into the boiler. In like manner, when the original level is restored, the float having risen with it, closes the cock. This arrangement keeps up a supply of water in the boiler as fast as it is diminished by evaporation; and this affords, at all hours of the day and night, an abundance of distilled and hot waters at little cost, as but one fire is used; and it is thus made to heat, at the same time, the bath and drying-chambers.

For technical operations and experiments on an extended scale and requiring the use of steam, the above apparatus will not answer without a supplementary arrangement; for the pressure of the steam generated in the boiler being greater than that of the external atmosphere, the water in the reservoir will not act alone; and we have, therefore, provided for a forcing pump. This pump is not shown in the drawings; but it is of ordinary construction, and worked by the hand. It connects with the pipe *x*, carrying the water from the reservoir to the boiler. The reservoir derives its supply of water from the hydrant through the service pipe *z*, and it should be fitted with a loose cover, which, while keeping out the dust, will allow an occasional in-

spection of the cock, as will be necessary to feel assured that it continues in good order.

The outlet for the distilled water and steam is through a tinned gas pipe of an inch diameter, which is attached by a coupling-nut to the nozzle *q*, projecting from the side of the valve *p*. This tube rises upwards to the top of the jack, when it is bent outwards and continued in a straight line to the opposite wall, where it is to diverge at angles by means of a T joint. To each end of these angular joints is fitted a stop-cock and connecting-pipe, turned interiorly, as above directed. One leads to the steam series, and forms the conduit for serving it and the still with steam; the other conveys away the vaporized water to the cooling-worm, where it is condensed into distilled water. These two cocks allow the use of either branch, as may be necessary; for when the boiler is generating steam, the cock on the branch leading to the condenser is to be closed, and vice versa, as it cannot be used simultaneously for both purposes.

The branches conveying the steam should be thickly enveloped with woollen list to prevent loss of heat by radiation.

The condensing apparatus consists of a block-tin worm and tub, very similar to that described when speaking hereafter upon the STILL. It is placed in a remote corner of the room and upon a high pedestal, so that there may be space beneath for a vessel to receive the distilled water as it trickles from the worm. This receiving-vessel is of blue or white stoneware, free from lead glazing, and made pear-shaped, with a flat bottom, and its narrow mouth kept always protected, by a suitable cover, against entrance of dust or absorption of acid fumes. A glass cock at the bottom is necessary for drawing off the water when it is needed for use. The tub is of zinc or galvanized iron, and bevelled at the rim, so as to present a bed or rest for a round-bottom pan, when it is desired to use it as an economical water-bath for large operations. The heat, in such instances, is derived from the water contained in the tub and surrounding the worm, its temperature being always high from the heat radiated by the aqueous vapors passing through the worm, in the act of condensing into distilled water. The water being the condensing medium, must, therefore, be replaced by cold water as fast as it becomes heated, otherwise the condensation of the vapors will be imperfect. To this end, there is a

small annular opening near the top of the tub, which connects with an external tube running down the side and out into the gutter. Complementary to this opening is another similar one on the opposite side and connecting with the hydrant, but with its tube passing into the interior of the tub, and down to the bottom. When the hydrant-cock is opened for the admission of cold water into the tub or cooler, the hot water being specifically lightest, rises as the cold water enters below, and flows out at the top through the exit tube. The bottom of this tub is fitted with a cock for drawing off hot water, as may be needed for washing or other purposes.

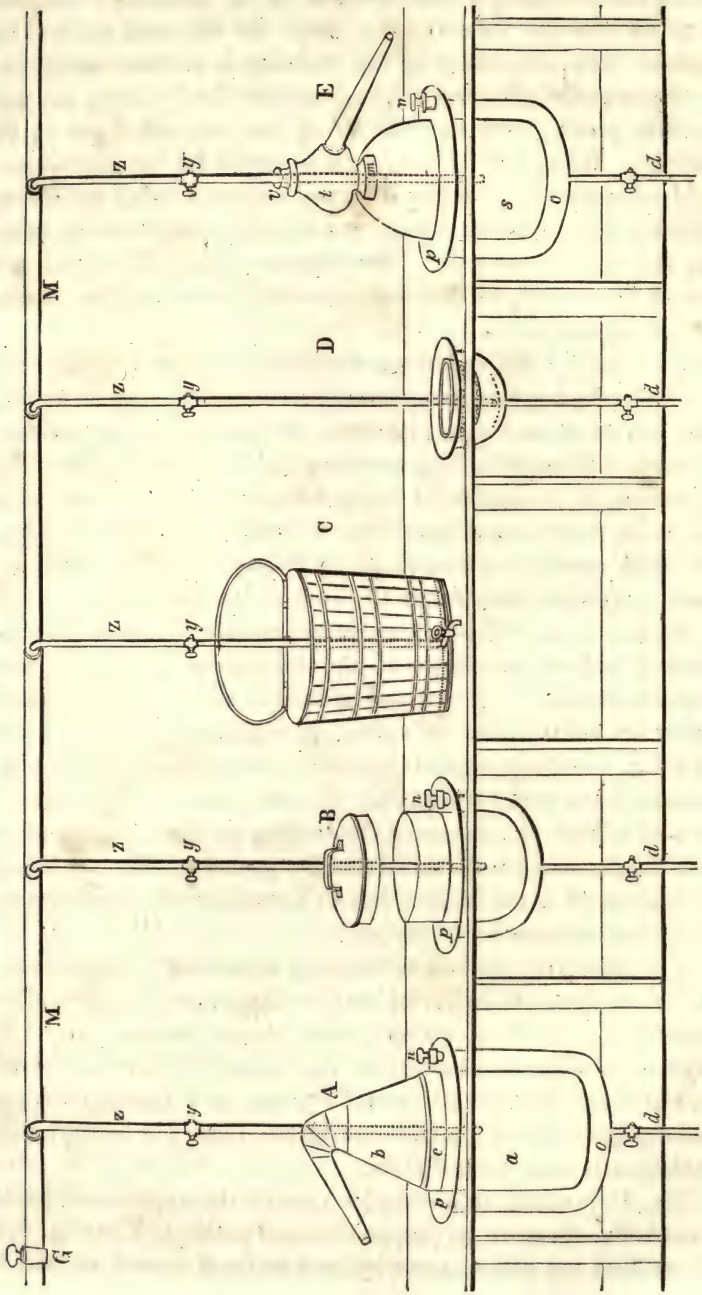
By means of this apparatus, one fire is made to heat the sand-bath and drying-chambers, furnish a constant supply of distilled and hot water, and generate steam for the various operations of heating, boiling, distilling, evaporating, &c. Besides these applications, it is capable of being adapted to many other minor purposes, which experience must determine, as it would require too much space to enumerate all its claims to be appreciated as a most serviceable assistant in the work of the laboratory.

Steam Series.—This is a range of implements designed for the nicer technical operations of the laboratory, or for extensive experiments requiring care and an easily manageable temperature below the boiling-point of water. It consists of five pieces, each of which has its appropriate service; and the whole mounted in a wooden framework rests against the back wall of the apartment, as at *f l*, Plate 2. Steam is the heating medium, and the necessary supply may be derived from the generator, Fig. 13, or any other form of steam boiler; but we have designed it, more especially, as an appendix to our jack.

The great and manifold advantages of heating by steam render the boiler the chief source of heat for the general purposes of the laboratory. In all operations which do not come within its degree of temperature, the use of the naked fire must be resorted to, but these cases are comparatively rare, and limited mostly to fusions, ignitions, and certain operations which will be more fully explained in their proper place.

Fig. 18 presents an intelligible view of the series, each implement being shown in its proper form and position. The first, A, is the still, of ten gallons capacity, and made of tinned copper, or

Fig. 18.



much better of block tin, about three-sixteenths of an inch thick. It is composed of two separate pieces; the body or lower part *a*, and the head or capital *b*, the latter being so nicely adjusted to the neck *c*, of the former, as to make a close joint when the two are put together, as shown in the drawing. Its lower part is enveloped by a jacket *o*, forming a steam chamber of two or three inches space between the inner and outer vessel. The rim of this jacket is a broad flange, serving to support the still by a corresponding flange around the circumference of its shoulder, and to make the connection steam tight, the flanges should be interposed with a piece of felt, and tightly bolted by nut-screws or clamps, as shown at *p*. The steam is introduced into the chamber, at the rear and just below the flange aforesaid, through a wrought pipe *z*, of three and a quarter inches diameter, branching from the main conduit M; the stop-cock *y*, in the middle, serving to shut off the current as may be required. Immediately in the bottom centre of the jacket there is a pipe *d*, leading downwards into a gutter, and fitted with a valve-cock, as a vent for the escape of condensed water and excessive steam.

To render the still available for distillations at temperatures below steam heat, there is a small circular opening *n*, through the united flanges, which leads into the steam chamber, and is fitted with a screw-cap for closing it when not in use. This opening or mouth is for the introduction of a funnel, which conveys water to the interior to form a bath, as may be necessary. Steam being then cautiously let on, the water-bath may be raised to any required temperature below 212° F. The worm and cooling-tub for this still are of the same form and material as described for Fig. 20, but their size is necessarily smaller, to correspond with that of the still.

It is scarcely necessary to remark, that as the mouth of the still body is wide and smooth, it may be used, without the head, as an open vessel, for infusions, evaporations, &c.

Next to the still is the steam-kettle, B, a double-bottom vessel, the interior of which is tinned copper or block tin, supported in a jacket exactly as described for the still, A. It is of five gallons capacity, and round at the bottom. The branch-pipe, exit-tube, valve-cock, and funnel-hole, have the same relative positions in

this piece of apparatus as in the preceding. A cover is provided for boilings which require its use.

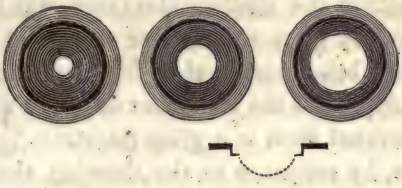
This kettle is particularly adapted for concentrating liquids by evaporation, making solutions of salts in hot water, and similar operations.

The centre-piece of the series is an iron-bound cedar tub C, of form shown in the drawing. It is of fifteen gallons capacity, and has a hinged cover for keeping out dust and retaining heat and steam vapors, through the back of which the branch-pipe descends into the interior of the tub, and ends at the bottom in a ring, perforated upon its upper surface with small holes for the better diffusion of the steam. When it is not desired to use wet steam, a close ring may be substituted for the calendered circle of pipe; and to this end, the upper and lower part of the branch-pipe are made separate, and screw cut at the ends, to be connected when necessary by a coupling-nut immediately below the cover of the tub. This arrangement is necessary for the convenient substitution of the open for the close ring, and vice versa. It must be added, however, that in the use of the close ring for a dry heat, provision is made for the escape of condensed steam into the gutter beneath by passing out the exit end through the side of the tub.

This tub is very convenient for making aqueous solutions of the soluble matters of plants, dye-woods, &c., whose active principles are liable to become altered by direct fire heat. It is, moreover, applicable to boiling purposes generally. A cock near the bottom allows the saturated liquid to be drawn off below, after which, fresh water being added, the boiling may be renewed. These alternate boilings and drainings may be continued indefinitely without the necessity of once removing the solid contents of the tub. To the right of the tub is the steam-bath D, which is simply a round-bottom bowl of iron, fitted with an exit-tube and valve-cock in the centre of the bottom, and after the manner directed for the other pieces of the series. The flange serves as a support for the containing vessels, which are set upon the top. To contract the top and adapt it to any size of vessel, there is a series of concentric rings, Fig. 19, made of iron plates, and fitting closely to the flange. The branch-pipe, instead of entering at the top of the jacket, is led in near the bottom, and made, by

means of a coupling-nut, to expand in a circle perforated with small holes throughout its upper surface. The steam ascending through these openings in forcible jets, strikes against the bottom of the vessel resting on the flange, and there condensing is reverberated as water, which finds escape through the valve-cock. This

Fig. 19.



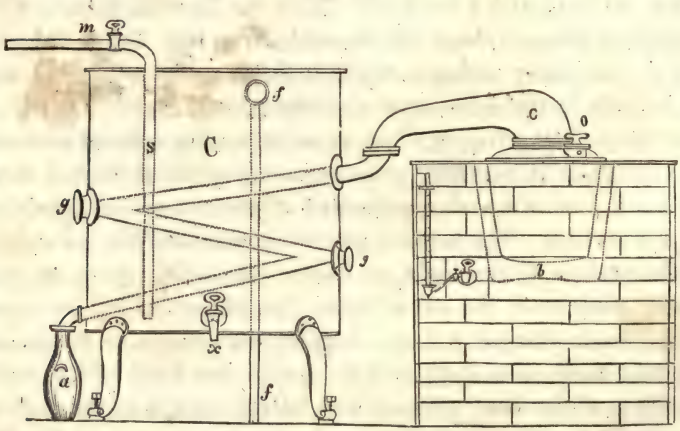
steam-bath is alike applicable to porcelain, glass, and metallic vessels, and will be found very convenient for evaporations in capsules and distillations in glass retorts; it being only necessary, in manipulating with the latter, to fit the ring with a wire basket for its support. The flow of steam must be gentle, else the vessel will be forced upwards by the confined steam, and possibly to its damage and that of its contents.

The last of the series is the stone still E. It is made of blue, salt-glazed stoneware after the form shown by the drawing, *s* being the body and *t* the head. Like the tin still, it rests, by a projecting flange around its shoulder, upon the rim or flange *p* and an iron outer jacket *o*, which is fitted with a valve-cock and funnel-tube in the same manner as the other jackets. The stoneware flange being fragile, when brought in close contact with the iron flange, it is necessary to interpose a piece of lead or thick felt cloth, and to use clamps instead of nut-screws for tightening the connection. The head of the still is movable, but fits closely to the neck *m* of the body, so that a steam-tight joint may be readily made with the aid of lute. To afford facility for introducing fresh charges without stopping the process or disturbing the tub, there is a stoppered hole *v* in the head of the still. The form of the head prevents any falling back, into the still, of any distillate which may condense in the former, and sends it all forward through the beak into an adjacent worm of the same ma-

terial as the still, and arranged in a cooling-tub after the manner hereafter described for Fig. 20. The branch-pipe which conveys the steam to the jacket of this still enters, as usual, in the rear and just below the flange; and it is proper to add, that the current must be gentle and cautiously regulated, as the stoneware is not capable of resisting as much pressure as metal. This still is used for the distillation of acid mixtures which might act upon metal; and of ethers and similar substances, which are manageable with difficulty in glass retorts over the naked fire or sand-baths. Moreover, being measurably free from any liability of breakage, it is adapted to the treatment of larger quantities than could be well operated upon in a glass retort.

It will be seen, by reference to the drawing, that the branch-pipes proceed, severally, from a single pipe M; and this latter is of welded wrought iron, and about one and a half inch diameter. It runs along the wall immediately above the series, and derives its supply of steam from the jack or generator, with which it connects by means of a coupling-nut. A cock, G, serves to regulate the current; and as the branch-pipes are severally supplied with a cock, it renders each vessel independent of the rest, so that they may be put in operation either singly or collectively. It is proper to add, that on first letting the steam into any one

Fig. 20.

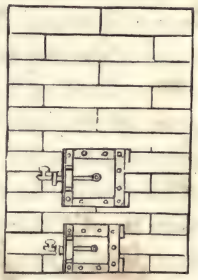


of the chambers, care should be taken to open the valve-cock, so as to afford free escape to the confined air.

When the still is to be an independent piece of apparatus, it should be movable, and constructed as hereafter described; but in those laboratories provided with a jack, the better plan is to make it a permanent fixture, and so arrange it as to make it useful either with the naked fire, or a direct current of wet steam from the jack, as the heating medium. Such a system, combining its advantages with those of the steam series and the jack itself, will render the laboratory most conveniently and economically efficient for every branch of chemical pursuit.

The arrangement best suited to this end, is shown by the foregoing drawing, Fig. 20. The whole is presented in front view, just as it appears when in operation. The brickwork, in which it is set, abuts against the chimney and connects with the flue through the furnace of the still. This furnace, instead of being in front, to inconvenience the operator with its heat and dust, is placed at the side or right end, as shown by Fig. 21, the lower door being the entrance to the ash-pit, and the upper to the furnace or fire-hole. The refrigerant or cooling-tub C, has its position to the left of the brickwork. All the parts are drawn to a scale of one inch to the foot; and their proper shapes are shown by the figures, to avoid the necessity of elaborate description.

Fig. 21.



The lower portion or body of the still *b*, is made of heavy sheet copper tinned interiorly. The head *c* is cast, wholly, from pure block tin. Projecting from the interior of the still, near the bottom, is a tinned copper tube, which passes forwards through the brickwork and ends in a stop-cock fixture, from which rises a glass tube. The cock serves to shut off communication between the still and tube, as may be necessary in case of accident to the latter; and the tube itself, graduated into inches, presents a scale which will at all times indicate the height of liquid in the still. This indicator is protected by a half casing of metal, in which it rests against the front wall of the brickwork, a clamp or two serving to keep it steady. The still has two supplementary parts, one of which is a culléndered lining of block tin, shown by Fig. 22, and the other a perforated false

Fig. 22.

Fig. 23.

bottom of the same material. The first is made to fit to the mouth of the still in such a manner that the same head will adjust with both the inner and outer vessel equally well. The latter is intended as a support for organic or other matters alterable by contact with highly heated surfaces, and is more particularly adapted for distillations with the naked fire. As it may be necessary frequently to remove this bottom, for the purpose of cleaning it or dispensing with its use in some operations, it is constructed of two parts, connected by hinges in the centre, so as to form a fold which will pass through the mouth of the still.

The block tin cullender, shown in the drawing of the still by dotted lines, is designed for use in the distillation of bulky substances, particularly those of vegetable origin, by a direct current of wet steam. It allows, in a degree, the application of the displacement principle in distillation, for as the current of steam enters, it passes upwards through the holes, thence through the mass of matter supported in the cullender, and the first portion of the distillate reaches the condenser saturated with the volatile parts of the substance under treatment, and without mixture of any, light, solid particles driven over mechanically, as would otherwise be the case. The process effects filtration at the same time that it constantly renews the surface of the solid matter to the solvent action of succeeding relays of fresh steam, while it also affords the means of determining when the former is exhausted, and the distillation should be stopped.

The steam-pipe is introduced through the opening *o*, and leads to within an inch of the bottom, where it takes an angular bend and ends in a rose, which is a perforated copper ball with a screw-cut shoulder, by which it is attached to the steam-pipe. The latter is so adjusted in the opening, by means of a shoulder and coupling-nut, as to form a tight joint. When the still is to be used with the naked fire *alone*, this pipe must be removed, and the opening closed with a screw-plug provided for the purpose. It should be remarked, that this opening serves also for the entrance of a funnel-tube through which to introduce fresh additions of liquid as may be required to maintain a supply in the

still, without the necessity of stopping the operation or removing the head.

The distillate, in passing from the still-head, goes into the worm firmly fixed in a cooler, C. The worm is a series of block tin tubes, as shown by the dotted lines. The mouth of the first joint receives the beak of the still-head, and that of the last joint empties, through a bent nozzle, into the receiving vessel, generally a glass or stone jar, as seen at *d*. To facilitate the cleansing of the joints, they are fitted at the ends *g* with screw-plugs, which being removed, allow free access to the interior with a cloth and ramrod.

The cooler is made of galvanized iron, or, still better, of tinned copper; and in order to accommodate the long joints of the worm which is soldered to it, its form is oval. The pipe through which it receives cold water is close to the side, and extends nearly to the bottom, as shown at *s*. A connection with the hydrant is made by a branch-pipe and cock, as shown at *m*. The opening for the exit of the warm water is seen at *g*, and leads into another pipe *h*, running down the outside of the cooler into the drain or gutter. A cock *x* serves for draining off sediment as it accumulates by deposition from the water.

We have left the framework or stand open in the drawings for the better exhibition of the different parts of the apparatus; but in practice it must be closed, so as to circumscribe the radiated heat, which would otherwise escape and be lost. There is, however, a door in front of each vessel to afford access within, as may be necessary for occasional inspection of the valve-cock.

The description of this apparatus will, itself, afford a fair idea of the great convenience of its several parts. Not the least important of its advantages is the readiness with which the pieces may be adapted to so many uses. Moreover, deriving its steam from the jack, which is always in operation, no fuel or time are wasted in getting it ready for service. It gives, too, an easily manageable heat, and is free from all the objections to a naked fire, particularly in the treatment of many vegetable matters, which are easily altered by the action of the latter.

When the laboratory is not provided with a jack or steam-generator, then the construction of the still must be somewhat different, and its position may be to the left of the furnace, as at

E H, Pl. 2. It should combine the double advantage of an adaptation to the heat of a direct fire, or that of a water-bath; and to economize room, it must be compact and movable, and therefore is set in a heavy, stove-like cylinder of sheet iron as a substitute for brickwork. The fire-door is as shown in the figures below, and in order to prevent the overheating of the iron cylinder, the part which contains the fire should be lined with a refractory earthen cylinder, of about two inches thickness, as at *b* and *c*, in Fig. 24. The smoke-pipe leads into the circular opening of the opposite flue. The body of the still rests upon the rim of this furnace at *a*, by its flange, which surrounds it immediately below its handles. It is shown by C, Fig. 25. Its dimensions should be so much less than those of the furnace, as to leave sufficient heating space around its sides and bottom. The material of the still is copper, and the joints are rounded so as to

Fig. 24.

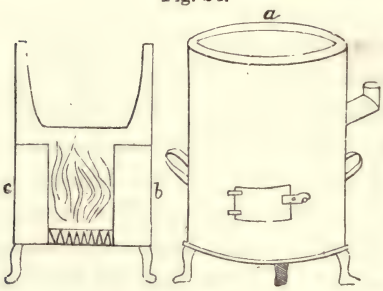


Fig. 25.

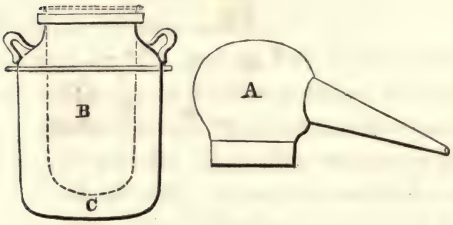
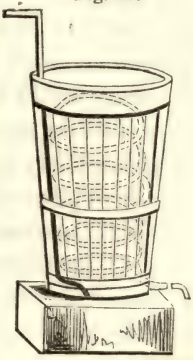


Fig. 26.



give every facility in cleansing. Moreover, round edges are less liable to become bruised than the angular. For the distillation of substances indestructible at high temperatures, this still is applicable over the naked fire, but for more alterable bodies, the intervention of water is necessary, and so, accordingly, an inner tinned copper or enamelled iron jacket is provided. The form

and position of this jacket are shown at B, by the dotted lines in Fig. 25. It is a straight cylinder with convex bottom, and a broad rim, serving also as a flange or rim for its support in the still. Its dimensions are four inches in diameter and eight inches in depth less than those of the still. The head or capital, which should be of tinned copper, or, preferably, of pewter, is shown at B. The rim is made to fit the mouth of either the still or water-bath, and hence the same head answers in both naked and bath distillations. The beak conveys the vapors accumulating in the capital, into the refrigerant or condenser, which consists of a pewter worm, Fig. 26, encased in a wooden tub kept constantly supplied with cool water through the pipe *e*. The water-pipe, which carries off the heated water displaced by the cold water, runs from the top of the tub and has its exit into the sink, or through the wall, into the gutter. These two pipes are better of lead. The vapors in passing through the worm are condensed, and drop as a liquid into a receiver, which is placed beneath the outlet pipe near the bottom of the tub.

To convert the apparatus into a water-bath (for in many distillations the temperature must not exceed the boiling-point of water or a saline solution), it is only necessary to charge the outer jacket, or still, with the proper quantity of liquid, and then to insert the inner casing B, which slides into the mouth and fits tightly.

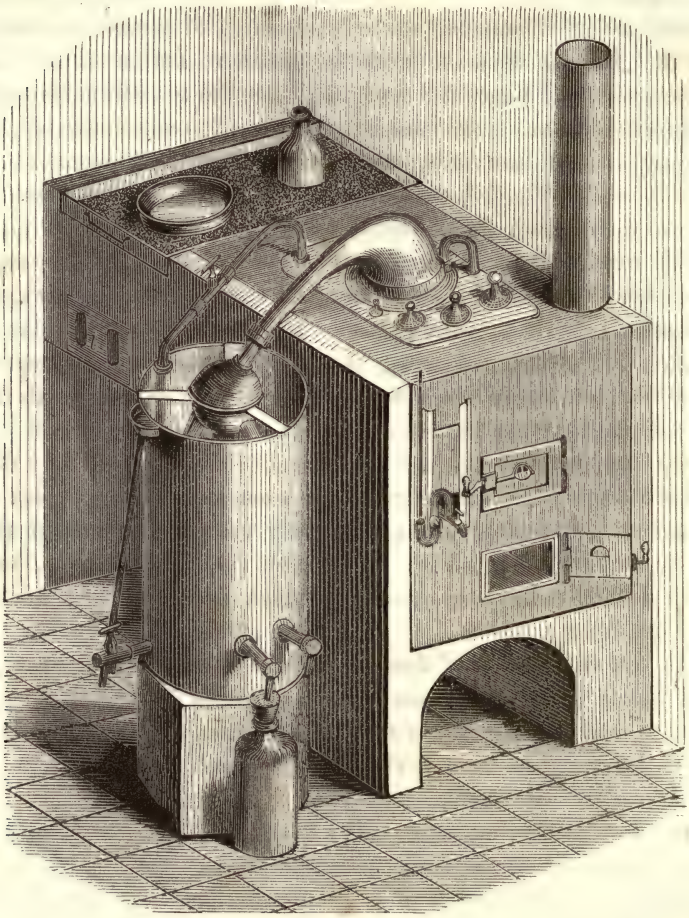
In the distillation of flowers, roots, and other substances, in the naked still, a too close contact with its heated sides and bottom renders them liable to injury by scorching, and therefore it is necessary to have a strong wire stand with one or two cullendered shelves upon which to place the material. The lower shelf *h* being an inch or two from the bottom of the still, prevents all liability of contact between it and the material. This apparatus is shown by Fig. 27. When the still is not in use for its legitimate purpose, by removal of the wire shelving, it becomes an excellent kettle for any of the ordinary boiling operations.

Fig. 27.

In the blank space of the wall to the left of the front entrance, stands a deal wood cask, with wooden spigot, mounted upon a

stand of convenient height. This serves as a reservoir for distilled water, and the opening in the top, for pouring in the water, must be kept tightly closed to prevent the admission of dust or absorption of gases.

Fig. 28.



Beindroff's Apparatus.—This utensil, Fig. 28, is not suited for very large operations, but, being compact and convenient in arrangement, will answer admirably for small laboratories. It combines many of the conveniences of the jack, and most of the requisites for general furnace business, such as digesting, distilling, macerating, boiling, decocting, dissolving, and evaporating.

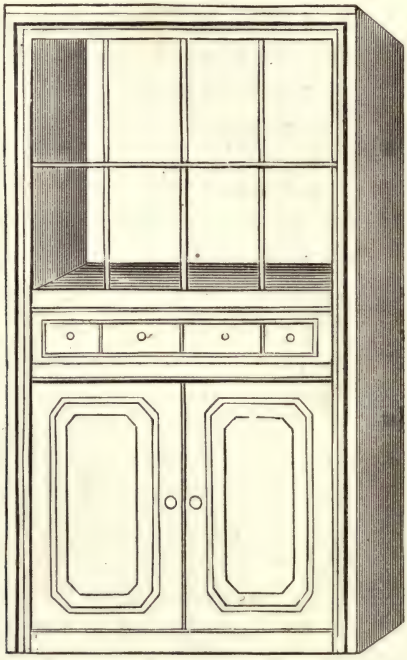
The whole is set in brickwork against a chimney-flue, and occupies a space of about four square feet. There is a furnace and grate in the brickwork for heating it by the naked fire when necessary; but there are arrangements, also, for the use of steam.

The framework is of copper, and constructed so as to act the double part of a boiler and a support for the smaller pieces of apparatus. To this end it is studded throughout with circular openings of different sizes, which are, severally, receptacles for a tinned copper still, a tinned copper evaporating pan, a porcelain and wedgwood capsule, a block tin digesting cup, and two other digesting cups of copper, lined respectively with glass and copper. There is also a hole for a steam-funnel for the support of retorts, dishes, &c., when a steam bath is desirable. All these vessels are surrounded by the boiler, which imparts to them its heat; and a small screw-plug in the top of the boiler serves as a connection for a steam-pipe, as may be desirable. The height of the water in the boiler is indicated by a glass tube properly affixed. A block tin worm or condenser and a cooling-tub are also accompaniments for the still, and to add still more to the efficiency of the apparatus there is a sand-bath on the top and a drying-chamber at the side.

Gas Chamber.—This is a very necessary appointment of every laboratory, as there are many operations which, in the cold, give off unwholesome vapors that should be excluded from the working apartment, and must, therefore, be conducted under cover; such, for example, as processes requiring the use of sulphuretted hydrogen, carbonic acid, and other gases deleterious in their effects upon the system or discomforting to the operator. The proper arrangement is a close framework set into the wall against a chimney-flue, or in such a position that a pipe leading from it may readily communicate with a neighboring flue. A dove-tailed window frame, divided midway by a strong and level shelf, will be appropriate for the purpose. It should have a height of six feet, a width of three feet, and a depth of sixteen inches. Four inches of the depth should be imbedded in the wall, and to insure perfect tightness, the joints should be closed with plaster. The part above the shelf is a common glazed sash hung with counterpoise weights, to afford facility of access and for viewing the interior during the progress of operations, without the neces-

sity of raising the window. The shelf is the table upon which the apparatus rests when in operation, and immediately below it is a range of small drawers for containing matters pertaining to the business of the chamber. The space beneath the drawers is divided down the centre and fitted with shelves and doors, so as to form a closet for storing the apparatus which may be needed for use in the chamber. The annexed drawing, Fig. 29, presents

Fig. 29.



an intelligible view of the structure. It is necessary to add that the noxious emanations find vent as they rise, through a perforated valve let into the chimney after the manner described at p. 19.

The Sink.—In the corner of the room to the right of the refrigerant, is the sink. Its position will be better understood by reference to I, Pl. 2. As it is necessary that the laboratory should be abundantly and constantly supplied with water for cleansing, distilling, and many other operations, it is better, in those cities where the water is supplied by public water-works, to

make an attachment to the main conduit, and lead the water through a lead pipe directly into the laboratory, and immediately over the sink. The only arrangement necessary is a stop-cock at the termination of the pipe, to regulate the flow of water. Fig. 30 represents a sink thus arranged. The trough may be of wood and lined with sheet lead, which metal is preferable to

Fig. 30.

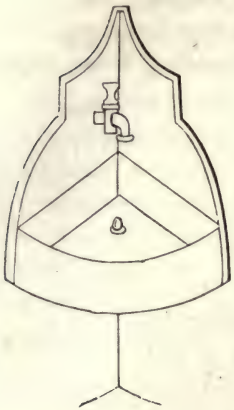


Fig. 31.

zinc, because less liable to corrosion by acids. It would be much better, however, to have it constructed wholly of soapstone, as this material possesses all the necessary qualities. The floor beneath, to a certain extent around the sink, should also be covered with sheet lead, otherwise its continual dampness from the splashing water would endanger the health of the operator. When the introduction of water by conduit is impossible, it is necessary to erect immediately over the sink a strong iron-bound oaken reservoir with cover, which must be daily filled with buckets from the neighboring pump. In either case, the exit-cock should be fitted with a diaphragm filter, Fig. 31, containing a stratum of crushed quartz, which arrests the suspended impurities of the water during its percolation through. If it is not convenient to provide one of the above filters, an economical but slower and less convenient one can be made of a common red earthenware flower-pot, by covering its bottom interiorly with a linen cloth and filling it with coarse white sand. The waste-pipe, which must be constructed so as to admit of the *free* discharge of the waste-water, is led, by a gradual descent, into a drain, which conveys its charge into cess-pools or tanks lined with bricks, and sunk into the ground. As the emanations of foul air from these pools are noxious, they should be placed some distance from the building, and kept well covered. If the situation be favorable, the drains should empty themselves into a gutter or some running

stream, which, in conducting away the foul matter, would relieve the air of the apartments of its noxious effluvia.

Fig. 32.

The mouth of the discharge-pipe must be fitted with a cullendered plug (Fig. 32) to arrest the passage of solid matters, which, otherwise, would fall in and prevent the egress of the waste waters.

As all the cleansing operations are performed at the sink, it is necessary that it should be fitted with several shelves, in addition to those which may be arranged by its sides. To afford free escape to the draining water, those

Fig. 33.

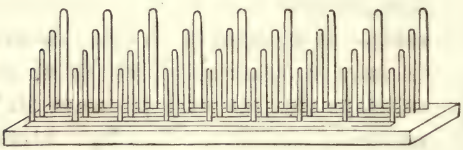
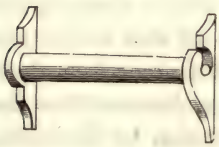


Fig. 34.

which are to hold the glass-ware had better be cullendered; and upon one, for the safety of the test-tubes and other hollow apparatus of too small circumference to stand upright alone, there should be a series of draining-pins, as shown by Fig. 33. A rack of horizontal pegs, for draining retorts and other irregular-shaped apparatus, might also be conveniently arranged upon a part of the space. For draining vials and small flasks, an upright stand fitted with pegs, as shown in Fig. 34, is perhaps preferable to the horizontal rack.

A jar of soft and a piece of Castile soap should have appropriate places in the vicinity of the sink; and near by also, say on the back of the door, for the sake of economizing room, there must be two long towels hung on rollers, as at Fig. 35. One of these towels is exclusively for the hands, the other for drying the cleansed glass-ware, &c. The other accompaniments to the sink are a coarse towel, a small paint-brush, a bottle of shot, a series of wires, some tow and raw cotton, and a wire instrument for the removal of corks from

Fig. 35.



the interior of bottles. This latter is nothing more than three plies of stiff wire united together at their upper ends, and bent in angular forms at their lower ends. A hair brush, like that shown by Fig. 36, for cleansing the sides of test tubes and cylindrical vessels, should also be provided. The paint-brush is for washing out wide-mouthed apparatus, and can be well substituted by a mop or twine-brush of similar shape, and much used in housewifery for washing tea-china. These and the cork-wires are to be had at any house-furnishing establishment.

Fig. 36.

Of the series of wires, one should be stiff and skewer-like, with pointed end, to remove those particles of dirt, tenaciously adhering to bottles, which have resisted the cleansing action of agitation with sand or gravel. The remaining wires may be of stiff iron and roughened, or jagged at the ends, in order the more securely to prevent the slipping of the tow or cotton, which is wrapped and tied thereon to facilitate the cleansing of the glasses. The tow or cotton is to be renewed as frequently as is necessary to cleanliness. A portion of the wires may be from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch thick, and 16 to 18 inches long. The rest for smaller apparatus may be of proportionably less dimensions. Several long wedge-shaped oaken sticks are also convenient for more effectually applying the cloth or towel, with which they are temporarily wrapped, to the angular spaces at the bottom of the glasses. For long tubes, flasks, and deep bottles, a ramrod with its screw end is a most efficient cleansing instrument, as it takes a tight hold of the cotton or cleansing rag and may be very dexterously handled. All of these pieces of apparatus should have appropriate places near to the sink. Pegs or nails are very convenient hangers, and two or four cuddies or drawers make serviceable receptacles for the tow, cotton, and rags.

In those situations where it is not convenient to introduce the water through a pipe, there must be erected immediately over the sink a strongly braced shelf, as a support to a closely covered deal-wood cistern for the reception of water. The water is supplied either by bucketfuls from a neighboring pump, or else is

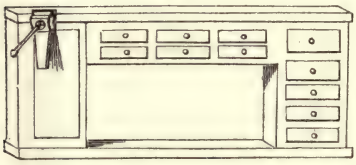
pumped in. In the former case, the position of the sink in the corner, and near to the door, allows great facility in filling it.

Next to the sink, occupying the inner wall-spaces on either side of the door, as at *m m*, Pl. 2, are strong shelving cuddies, racks, and pegs, as receptacles for crucibles, furnaces, iron pots, pans, lead coils, and other apparatus needful in the processes and operations performed in the room.

The corner shelves K, Pl. 2, strongly built, are for the reception of the larger pieces of apparatus. There should also be reserved a wall space for the still, generator, &c., when out of use.

The anvil occupying the position L, Plate 2, and resting upon a foot-block, is a most useful implement, and a necessary accompaniment to the tool-chest, upon the opposite side of the room, at *n*, Pl. 2. This tool-chest, which is shown by Fig. 37, combines in its construction the conveniences of a work-bench. The vice is affixed towards the end, so as to give full working room. The drawers are receptacles for the requisite tools, among which should be a hammer, hatchet, saw, a chisel of each kind, gimlets, awls, files of the various shapes, pincers, a soldering iron, a screw-driver, with an assortment of screws, nails, &c. A glue-pot will also be found a necessary addendum. The bench should be about four feet in length, and of height suitable to the comfort and convenience of the operator.

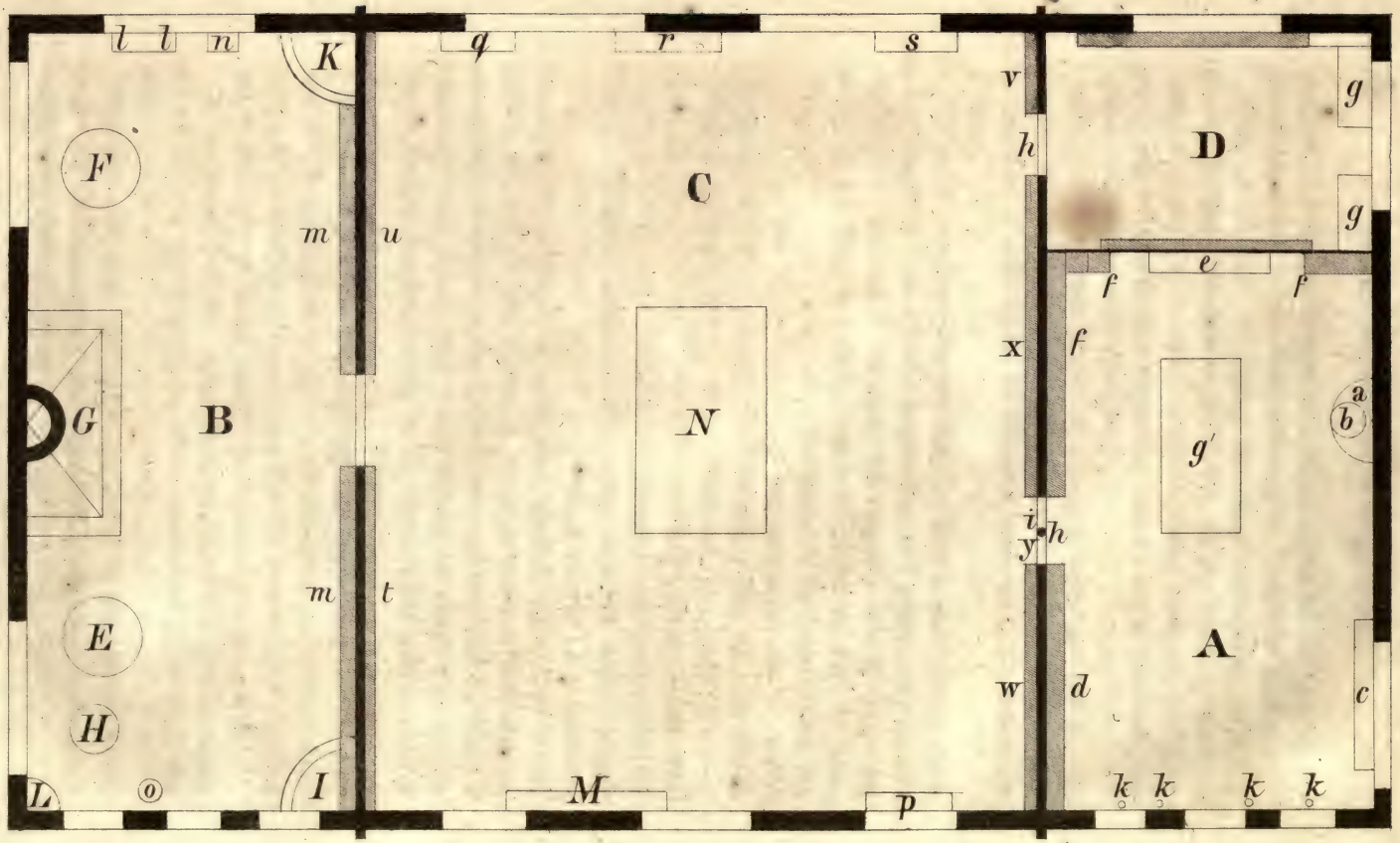
Fig. 37.



The pedestal *o*, Pl. 2, occupying the space between the door and left front window, supports a pear-shaped reservoir of deal-wood, or preferably of blue stone, for the reception of distilled water, a supply of which should be constantly kept on hand.

A tin match-box, an essential requisite of the furnace-room, should have a dry position in some convenient place upon the wall.

The charcoal, coke, and sand can either be kept in the cellar, or else in bins occupying the base of the shelving, and resting immediately upon the floor.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A solid oaken pedestal for the iron mortar, and several wooden buckets for general convenience, are also necessary pieces of furniture.

All operations emitting corrosive or disagreeable vapors should be confined, as far as possible, to this room. In passing sulphuretted hydrogen, chlorine, or sulphurous acid through liquids, the vessels should rest either upon a shelf projecting out of the window, or else under a hood which can carry the emanations into the flues, and thus prevent much corrosion of apparatus and discomfort to the operator.

CHAPTER IV.

THE OPERATING-ROOM.

Between the office and the furnace-room, and occupying the whole residual floor-space C, Pl. 2, of the apartment, is the main operating-room (Pl. 1), of dimensions on the plan, 24 by 18·6 feet. In this room are performed all the more delicate manipulations of analysis and experimental research, and hence the necessity of great cleanliness. The prescribed arrangement frees it entirely from the dust of the coarser operations of the furnace-room (the door of which should be kept constantly closed), while the perforated register, before recommended, and counterpoised windows, of adequate dimensions to afford abundant light, promote thorough ventilation. In this room is stored nearly all the finer apparatus and materials. The main feature of the apartment is the operating-table, which is shown by Fig. 38. Its position (M, Pl. 2) is against the front wall-space between the middle and left window. It may be constructed of pine wood, though cherry or

Fig. 38.

walnut is preferable. At all events, the top, which must project over all around 2 inches, should be either of these woods or ash, and at least of an inch thickness; glued at the grooves, and grooved and clamped at the cross-grained end, so as to prevent warping or shrinking, either of which creates a great inconvenience to the operator. It is indispensable that the stuff be old, well seasoned and joined, because any shrinking will form cracks and crevices for leakings to penetrate into the drawers beneath, and injure their contents. When the top is made of common wood, it should be covered with india-rubber cloth, drawn tightly over, and fastened under the edges by copper nails. The height of the table proper is 3 feet. Depth 2 feet 4 inches. The length of the top is 5 feet. The shelf-stand or test-case, which slides in grooves, and is fastened to the top of the table by screws, is 30 inches in length, and 30 to 32 in height. The distance between the shelving is unequal, in order to accommodate the different sized bottles. The space between the lower and first shelf may be 7½ inches, diminishing gradually upward, so that the interval between the top and topmost shelf shall not be greater than 5 inches. The shelves may be of light stuff, say ¾ inch thickness. To protect the bottles from dust, the test-case should have a glass front, hung with counterpoise weights in the manner of a window sash, so as to afford facility in raising and lowering it. The upper drawers should have a depth of 2¼ inches; the lower 3½ inches. The closets below should be fitted, the one on the right, with movable shelves, the other on the left with rows of wooden pegs, obliquely hung.

All the knobs should be of that kind known as "*White Argillo*," both on account of their durability and neat appearance.

This table thus constructed is the operating-table of the experimenter, and must be furnished with such apparatus and materials as are in constant requisition, and hence the convenience of the shelving, drawers, and pegs, as their receptacles. As it is desirable that the table should not be encumbered with apparatus in unnecessary amount, only those pieces which are of constant use, and required to be at hand, should find an abode within the limits of this table. The general supplies of the laboratory are stored elsewhere, as will be directed hereafter.

One of the upper drawers should be reserved for filters, of the different kinds of paper used for the purpose. These may be purchased, already cut, and of the different sizes, neatly put up in boxes. If they are made in the laboratory, it is necessary to have a series of circular tins, corresponding with the size of the funnels most in use, by which to shape them.

Another drawer may be reserved for small tubes, rods, pipettes, and glass or porcelain connections. Another for platinum crucibles, spatulas, and fine metallic vessels.

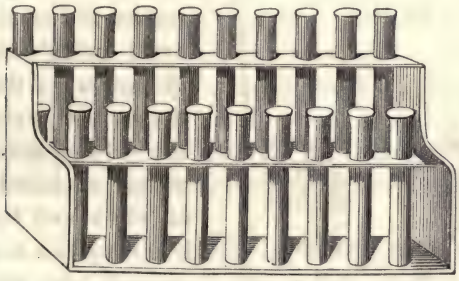
The small retorts, bulbs, and the like, should also have an appropriate drawer. The larger retorts and glass apparatus find appropriate places in the cupboards.

The top drawer to the extreme right should be fitted up in desk-form, and furnished with pen, ink, and paper, for the convenience of making rough notes during operations, which are afterwards to be neatly transcribed in a note-book, or "Record of Laboratory Operations," kept especially for the purpose in an appropriate place in the office desk. The valuable information which can in this way be stored up, in a short time, amounts to a vast fund, and will serve, to the great convenience of the writer, as a remembrancer of facts acquired and of errors avoided. A coarse towel should always be an accompaniment to this table, and have a hanging position at its side.

The two lower drawers beneath the closets may be reserved for the more weighty implements.

A leaden funnel, supported by a wooden casing, with its barrel

Fig. 39.

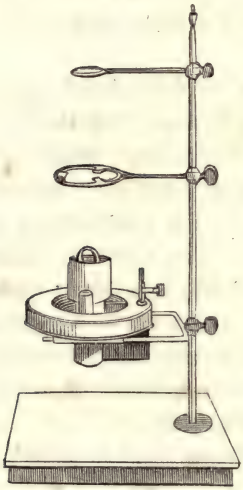


united to a leaden pipe leading through the floor into the street

gutter, and placed immediately to the right of the table, would be very convenient for receiving and conveying off the slops from the test-tubes. When this arrangement is not practicable, a bucket of india-rubber must be substituted; for the practice of emptying test-tubes upon the floor is slovenly and reprehensible, and by keeping it constantly damp, the comfort of the operator is greatly disturbed.

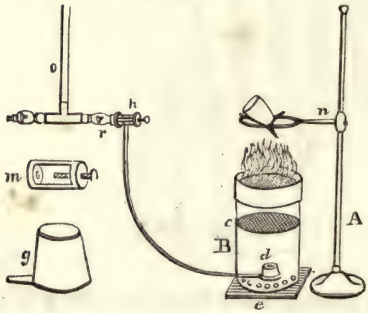
A rack with test-tubes, Fig. 39, may be considered one of the fixtures of the operating-table.

Fig. 40.



The spirit-lamp which furnishes the heat for table operations, and is shown by Fig. 40, will be spoken of more fully hereafter. When coal gas can be commanded, it is far more convenient and economical, and by a particular arrangement, may be made to yield heat enough for evaporation and ebullition in capsules, and the different operations of digesting in bell glasses, &c. By the use of a large Argand burner fixed over the jet of the table blow-pipe, we can obtain the power of a blast. The admixture of the gas, in this way, with atmospheric air, increases the heat to such an extent as to allow the ignition of precipitates in crucibles, and the accomplishment of many other minor operations, which formerly required the use of a furnace. The arrangement by which these results are attained, so as to avoid entirely the deposition of carbon on the bottoms of the vessels, is shown by Fig. 41. B is a cylinder of sheet copper, stretched over the top of which, and fastened by an iron hoop, is a fine wire gauze, covered with fine gravel to protect it from wear and

Fig. 41.



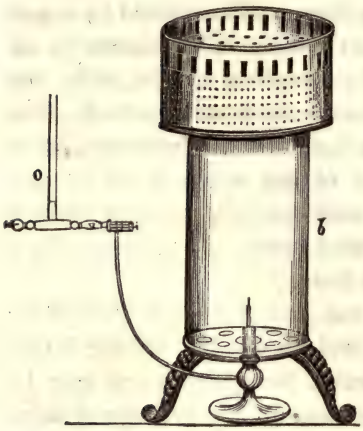
tear. In order to promote a more thorough admixture of the gas and atmospheric air (which is effected in the chimney), there is a coarse wire gauze diaphragm *c*. The flexible gas-pipe of vulcanized india-rubber depending from, and connected by a gallows screw *h*, with the permanent hanger *o*, terminates in an argand burner *d*. To prevent a scorching of the table, the burner and cylinder both rest upon a thick metallic foot. The air enters through the openings in the lower circumference, being drawn up by the upward current of gas, which is let on and regulated by the stop-cock *r*; and the mixture thus formed passing through the upper fine wire gauze, above which it is ignited, should burn with a bluish flame.

"Where the quantity of gas is too great for the amount of air admitted, the flame will be white and smoky, but by regulating the supply of gas, the due proportion for a blue flame may be easily attained. To obtain a blue flame from a cylinder of large diameter, a considerable quantity of gas will be requisite, and hence an economical advantage is gained by employing cylinders of different diameters. In the same cylinder, also, where different quantities of heat are desired, the lower series of holes may be made large, and a ring of sheet-iron slid over them, by which the quantity of air admitted may be regulated according to the quantity of gas consumed. The cylinders may be 2½ to 5 inches diameter by 6—8 inches in height; but by introducing several pieces of coarse gauze *c*, at short distances apart, the height may be diminished. The highest amount of heat produced by this apparatus is a cherry-red by daylight. For burning off filters in a platinum crucible, a cylinder of 2½ inches diameter is amply sufficient; but for heating larger vessels, such as capsules, those of 4—5 inches diameter are desirable. This mode of burning the gas presents the advantages of producing any degree of heat as high as a red, of not blackening vessels immersed in the flame, and of avoiding, with more certainty, the fracture of porcelain or glass vessels, from the diffusive character of the flame."

The ring *n*, sliding upon the rod of the upright stand *A*, serves as a support for a retort, capsule, or crucible. A second chimney *g* placed over the crucible creates a uniform and constant draught.

Very neat gas furnaces are made by W. F. Shaw, Boston. Those for laboratory purposes have a broad base, as shown in the drawing—Fig. 42—to steady their position on the table. Surmounting the wire gauze diaphragm is a perforated cylinder, with large openings near its top circumference for the promotion of influent air-currents. These, by perfecting the combustion of the burning mixture of air and gas, not only increase its heating power, but prevent all smoke and odor. It is necessary to add, that the meshes of the wire gauze should be kept clean by the occasional application of a tooth-brush.

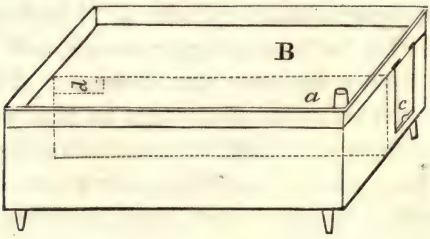
Fig. 42.



The whole of this apparatus is movable, and when the space which it occupies upon the table is required for other purposes, it is only necessary to disconnect it from the hanger, and place the whole aside, to be as readily replaced again when wanted.

The introduction of gas into the room also allows the use of a convenient table sand-bath, for certain operations which require the constant supervision of the operator. It consists of a copper

Fig. 43.



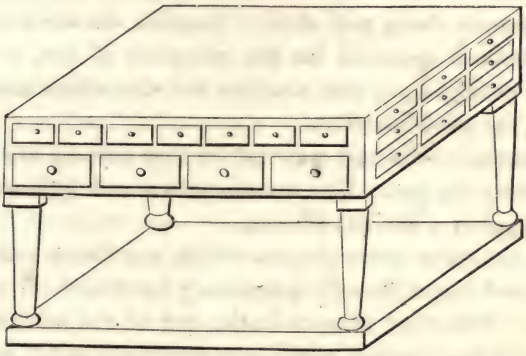
box B, eighteen inches long, twelve inches wide, and six inches deep. The top, which is ledged, projects over about an inch, and forms the bed for the sand. The door *c*, having a small semicircular opening at its base, is for the entrance of the gas

pipe with an argand burner attached, as well also for the supply of air necessary to sustain combustion. The fire thus applied heats the sand on the top. The heated air has an exit through the circular aperture *a*, after having traversed the interior, which is divided lengthwise by the partition, as represented by the dotted lines. The communication between the apartments is by an opening *d*, in the diaphragm. In this way we obtain a graduation of the temperature of the bath. The Swedish chemists improve upon this construction, by annexing an apartment for drying filters and precipitates as well as for keeping liquids hot while filtering.

These, with the test-bottles and contents, complete the paraphernalia of the operating-table, and so we proceed to describe the next most important piece of furniture of the room.

The Centre or General Table.—This table (N, Pl. 2), compactly fitted to serve the double purpose of an operating-table

Fig. 44.



for distillations, and other large general operations of the laboratory which would occupy too much room upon the smaller table, has its top, also of cherry, projecting two inches all around, and grooved, glued, and tightly jointed, as directed for the preceding table, like which, its lower portions may also be of white pine. Its proper position is near the centre of the room, so as to afford free access to all of its sides. Fig. 44 gives a view of it. Its dimensions are 2·10 feet height; 6·6 feet length; and 3·4 inches breadth. The legs are fitted to a bed, which is to be firmly screwed to the floor, so that the table may

be stationary and firm, as any jarring may create serious damage to a delicately arranged apparatus.

The drawer space should not exceed 15 inches of the whole height of the table. The end drawers are necessarily, from the construction of the table, very short, and may be omitted entirely, though it is better policy to have as many receptacles as possible, for they will all be found useful as well as convenient.

Of the front drawers, one should be appropriated exclusively to the sheets and other articles of india-rubber. Accompanying these must also be a pair of shears and a ball of very fine linen twine for fashioning and securing joints. Another drawer must be reserved exclusively for the corks of assorted sizes. Two smaller apartments or divisions are also necessary, one for the files of different sizes and shapes, and the other for the cork-presser, and borer, of which more will be said hereafter.

The stock of filtering paper is also kept in another of these drawers; and with it, the circular tins by which it is cut into different sized filters. The shears for cutting the paper should be kept always sharp and clean. Another drawer divided into compartments is required for the reception of tow, raw cotton, bladders, string, &c.; and another for the clean dusters and towels of the establishment.

The filtering-cloths and material for that purpose are also kept in a separate drawer. The thermometers and hydrometers are likewise kept in a distinct drawer.

There are many other articles which are better preserved in drawers, and hence there is a necessity for the whole number in the table. The short drawers in the end of the table can be reserved for minor matters, such as the writing-diamond and similar implements.

The lower bed of the table forms an excellent shelf for the filter-stands, retort-holders, clamps, supports, and other wooden apparatus in frequent use upon the operating-table.

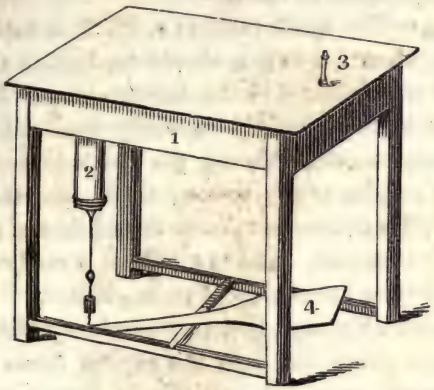
All the iron stands and similar apparatus should be painted with black varnish,* in order to preserve them from rust. In

* To fused asphaltum, 40 ozs. add a half gallon of boiled linseed oil, 6 ozs. each of red lead and litharge, 4 ozs. dried and powdered white copperas. Boil for two hours, then mix in 8 ozs. of fused dark amber gum, and a pint of hot linseed oil, and boil again for two hours more. When the mass has thickened, withdraw the heat and thin down with a gallon of turpentine.

the selection of iron hollow-ware for purposes of ebullition or evaporation, that which is lined with enamel should be preferred, for it is convenient, readily cleansed, and not much more costly than the naked iron ware.

The mouth blow-pipe table, occupying a position against the front wall, and immediately under the right window, as shown at

Fig. 45.



p, Pl. 2, is an indispensable piece of apparatus, which will be more fully spoken of under blow-pipe operations.

The blast or pneumatic table (shown in position at *q*, Pl. 2), which is sometimes also called the table blow-pipe, may be considered as an implement indispensable to the chemist, it being alike useful for bending glass tubes, blowing bulbs and other small apparatus, and for rapidly effecting the decomposition and ignition of substances, which, for their fusion, would require an ordinary wind furnace. The most convenient form of this apparatus is shown by Fig. 45. It consists of a brass cylinder piston 2, worked by a treadle, which drives the air into a large tin box enclosed in a framework 1, immediately under the top of the table. From the front end of the box a tube rises through the table top, and terminating with its small jet within the interior of an Argand burner, urges the air directly upwards, producing a full flame. The Argand burner may be connected with a lamp or reservoir, containing a solution of oil of turpentine, or alcohol, or with a gas-pipe. In using spirit, the burner must have

Fig. 46.

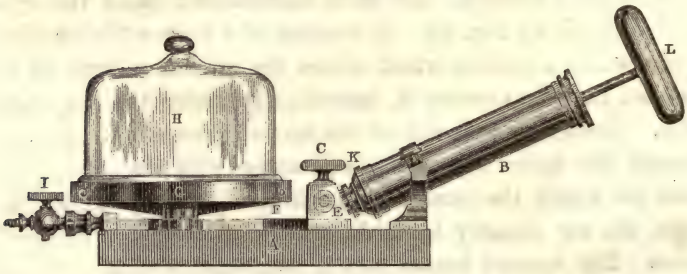
a circular wick with a contrivance for adjusting its height. Gas, however, when it can be conveniently obtained, is now generally used, on account of the greater power, convenience, and manageableness of its flame. An approved form of Argand burner, for laboratory service, is shown by Fig. 46. Being constructed with a porcelain cap, the holes through which the gas arises are always clean and free from stoppages by rust or other imperfections incident to metal.

Air-Pump.—The small table at *r*, Pl. 2, is used for the air-pump, which, when not in use, should be kept in an appropriate place in one of the cases in the balance-room. Being a costly apparatus, it is now almost exclusively replaced by syringes, which are more economical and not much less convenient, as made for the purpose at the present time. For the convenience of uniformity, the attachment screws should have a thread similar to that of the stop-cock, so as to admit of a ready adaptation to each other when an attachment is to be effected.

The Pneumatic Syringe is a very serviceable implement. It serves for exhausting air from the various forms of vessels in numerous experiments, and particularly from tubes in organic analyses and similar operations. It is also useful in analyses, for evaporations and dryings under an exhausted receiver and over sulphuric acid, or other hygroscopic substance, as will be mentioned hereafter, under the proper heads.

To preserve the efficiency of this piece of apparatus it must be frequently worked, and to prevent leakage at the joints, the latter as well as the piston must be kept well oiled.

Fig. 47.

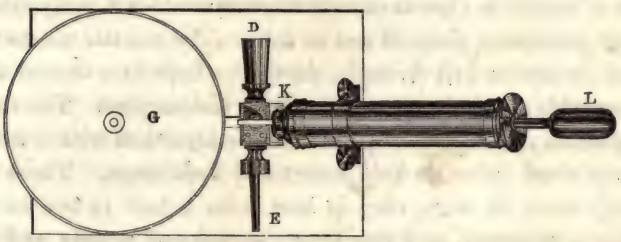


The most convenient form of Pneumatic Syringe is shown in side view and plan by Figs. 47 and 48. When in use, it is fast-

ened firmly to the table by means of a screw-clamp made expressly for the purpose.

The base A, is a solid piece of mahogany, to which the pump arrangement is firmly attached by screws. The barrel B, 9 inches long, by 1⅓ inches diameter, is of brass, and carries an air-tight piston, having an ordinary silk valve opening towards the handle L. There is a second valve also at K. A four-way cock C, allows the air to be drawn through either of the nozzles D and E; and a tube F, connects this cock with the ground glass bed-plate G, which is surmounted by a glass bell receiver H. The edges of the receiver are ground perfectly smooth and flat, and should be greased, so that, when set upon the bed-plate, it may form an air-tight joint. Connection is made between the receiver and atmosphere by means of a cock, I. To this latter there is a screw adjustment for attaching a flexible india-rubber tube in tube manipulations.

Fig. 48.



The construction of this instrument is such as to render it not only efficient, but also convenient for general laboratory purposes. Tubes may be connected at either end of the cross-piece D, E, as well as at I; and the bell serves for all the analytic operations of drying and evaporating.

The table *s*, Pl. 2, to the right of the air-pump, is a stand for the common scales of the laboratory, which are useful for testing the weights of materials purchased and for weighing coarser articles in large quantities. A cheap platform balance with a movable tin dish answers conveniently for this purpose. The accompanying (Avoirdupois) set of weights should range from ¼ oz. to 8 lbs.

The next fixtures to be described are the cupboards. Those affixed to the partition of the furnace-room, as at *t* and *u*, Pl. 2,

are more properly shelves, with curtains instead of doors to protect their contents from the dust. The set *t* may be occupied with the leaden coils, wooden and coarser apparatus of the apartment. The curtains of common muslin, rendered fire proof by immersion in a solution of borax and sal ammoniac, and drying, are hung by means of small brass rings upon an iron rod running the whole length of the cap of the shelving; and in order to keep them distended, leaden bullets should be sewed at occasional distances upon the lower ends. The shelving *u* ascends to only half the height of that of *t*, because the upper space is to be reserved for racks and rings. The shelves are intended as receptacles for the porcelain capsules, crucibles, &c., the bell, beaker, and other similar glass apparatus, care being always taken to place the larger and heavier articles upon the lower shelves. The tube rack is nothing more than a series of pegs, placed closely adjoining in a straight line and inclining upwards, so as to prevent the tubes from falling through. This open work presents the whole stock of tubing to view at one glance, and enables a ready selection of any particular piece of rod or tube. The smaller pieces which would be apt to fall through, should be kept in a drawer of the centre-table specially appropriated for the purpose. The remaining portion of the upper space must be furnished with a series of various sized spikes to hold retort and flask rings. These rings, readily made of wire, vary in size from a half to two or more inches in diameter, and receiving the necks of retorts and other curved or bent apparatus, retain them in a safe and convenient position. The rings may also occupy any small vacancies upon the walls for the use of such a portion of the apparatus as the cupboard cannot contain.

The small cupboard (*v*, Pl. 2) in the corner opposite, may be used as a sort of general cupboard for very nice little matters, which require great care and cleanliness in their preservation. The door consequently should be fitted with a fastening and kept constantly closed when not in use.

The cupboards *w* and *x* erected against the partition opposite, and occupying the spaces on either side of the entrance into the office are, the one *x* for the stock of drugs and chemicals; the other *w* for the new empty bottles, to be confined to the lower shelves, and for the specimens that may from time to time be ac-

cumulated by the labors of the operator. The lower half of the cupboard X should be furnished with small drawers similar to a druggist's case. These are for the dye-woods, sulphur, chalk, and other similar coarse articles of stock, which are more securely kept in this way than in bundles, which are liable to rupture and damage by rough handling and by retaining moisture. The upper shelving is to be exclusively occupied with the articles in bottles, which are to be arranged in classes, the compounds of each base forming a class. The mineral and vegetable acids and organic compounds, have also each a separate position. The weightier articles, as elsewhere directed, should always occupy the lower shelves, both for convenience of handling and on account of the greater stability and power of bearing heavier weights than the upper shelves.

The "black-board," *y*, Pl. 2, made of artificial slate, is hung sash-like between the uprights of the cupboard *w* and *x*, and, being counterbalanced by weights, can be lowered or raised at will, and thus leaves free access to the office. For rough calculations and plans, drafts of apparatus, diagrams, &c., the black-board is very convenient. When a hand-slate is substituted, the pencil should be of talc (French chalk) which makes a more distinct mark than the common slate-pencil, and gives more facility in writing. These pencils are now sold in most of the stationery stores.

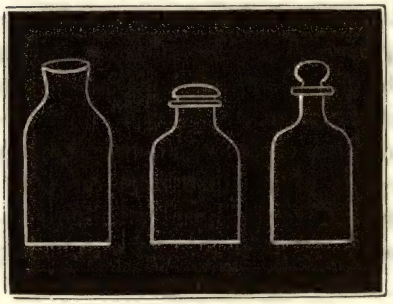
Bottles.—Particular regard must be had to the shape and material of bottles for laboratory use. Those intended for holding acids or salt solutions, must be of well-annealed glass, which is free from lead, and can resist the corrosive action of their contents. Some glasses, containing an excess of alkali, gradually lose their brilliancy by absorption of moisture from the atmosphere; others again are attacked by acid and alkaline solutions; and some, indeed, even by prolonged contact with boiling water.

The inalterability of glass by air or chemical agents (hydrofluoric acid excepted) is proportional to its hardness and infusibility. Flint glass is the most brilliant and comparatively fusible, and its consequent pliability renders it available for thermometer and barometer tubes, but as material for chemical vessels it is far inferior to the Bohemian glass (a silicate of potassa and lime,

with large traces of alumina), which is harder, lighter, and while possessing many better qualities for chemical ware is, when well made, scarcely less remarkable for beauty than crystal lead glass.

Care must be taken in the selection of glass apparatus, especially those which are to serve as implements for reactions, to choose such as are free as possible from striæ, knots, or bubbles, —defects owing to the imperfect mixture of the materials of the glass. They should have great uniformity throughout both as to material and workmanship. The more transparent the glass, the more readily can the interior cleanliness of the vessel be ascertained. The common green glass bottle from the factories of New Jersey, in the absence of better, answers every purpose for the common acids, coarser dry substances, and the solutions of such as are soluble; and are, moreover, economical. For the reagents and finer chemicals, there is a cheap kind of white glass, free from lead, now manufactured in Philadelphia, and which is well adapted to the purposes, and satisfactorily replaces the elegant, but, at the same time, much more costly imported Bohemian glass. The laboratory series should vary in size from one ounce to one gallon, ranging as follows: 1, 2, 4, 8, 16, 32, 64, 128 ounces. The most approved shapes are shown by the cuts below. Fig. 49 represents a wide-mouth bottle for powders and crystals. It is short and wide, with round shoulders to admit of ready emptying and cleansing, and has a strong tall neck for tightly corking. The corks should be perfectly smooth and of the velvet kind. This shape is equally applicable to the bottles of white glass, as is also that of the narrow mouth, glass stoppered, as shown by Fig. 51. The narrow necks and their stopples must be accurately ground, so as to insure perfect tightness. As the cost of this white glass above mentioned is so very little greater than the Jersey green, it would probably be more advisable to purchase

Fig. 49. Fig. 50. Fig. 51.



the whole suite of bottles of such material. The stopples of the narrow-necked bottles are made nearly spherical, but somewhat flattened on the top to project over the mouth so as to protect it from dust. The lips are flat and stout for pouring readily. The wide-mouthed stoppered bottles are, as to body, similar in shape to the above, but their stopple-heads are flattened, and cover both the mouth and the rim. The series of all these bottles consists of the sizes above mentioned. For one or two substances both in solid state and solution, which are sensitive to the decomposing influence of the light, nitrate of silver and protochloride of mercury, for instance, it is necessary that the bottles be either of dark-colored glass, or else covered exteriorly with tin foil. For hydrofluoric acid, a lead or gutta percha bottle is necessary, as glass is decomposed by that body. All solutions should be kept in ground-stoppered bottles; and if economy is indispensable, let the series consist of as many of the green glass bottles as possible, retaining only as many of the white Bohemian glass as are absolutely necessary for the finer reagents. Corked bottles are inconvenient and liable to leakage, and their use as permanent receptacles of liquid should, if possible, be entirely discarded. We have consequently not given the shape of a narrow-mouthed unstoppered bottle, though, if they are preferred, the shape of Fig. 51, without the stopper, must be the pattern.

All bottles with contents must be labelled in full and with symbols. This injunction as to labelling applies with equal force to the beaker glass upon the sand-bath and the capsule over the lamp, and to every vessel resting upon the shelves or employed in operations, which contain any substance or solid, whether the material or product of any process. An omission of this precaution frequently leads to much confusion, and occasionally to serious errors. Thin writing paper glazed upon one side with a solution of gum tragacanth, and divided into small squares of different dimensions to suit the several sizes of vessels, answers very well for the purpose of labelling operating vessels; but the blue-bordered labels of the shops are much more convenient, and fully as cheap; their cost being 12 cents per box containing from 100 to 500 labels, according to the size of the latter. With a pencil, or more properly pen and ink, the designation may be

written on the label, and thus completed, it is to be pasted on the bottle. For bottles containing the chemicals, materials, &c., these paper squares are equally applicable, but for the test series, upon which the labels are to be permanent, it is better that the names be etched upon the glass by the action of fluohydric acid. Indelible labels may also be made extemporaneously, according to Schubert's suggestion, by writing the letters on paper with a solution of one part of oil of vitriol in six parts of water, drying, and then exposing it to a *moderate* heat. The written letters being thus partially carbonized, form an indestructible label.

For writing on glass, Brunnquell proposes the use of a crayon formed by melting together 4 parts of spermaceti, 3 parts of tallow, and 2 parts of wax, and when the whole is fluid, stirring in 6 parts of red lead and 1 part of potash.

Bottles are now made with indelible names in black enamel, upon a white ground; and where economy is an object, the annexed label (Fig. 52), published by Bullock & Crenshaw, Philadelphia, from our design, will be found an excellent substitute. It expresses the full name of the article, with its symbol; and, having a carbon ground, will, when varnished with a benzole solution of caoutchouc, present an indestructible surface.

Fig. 52.

Let it be a cardinal rule of the laboratory, that no experiment or operation shall be abandoned even for a moment without having the containing vessels labelled. Those bottles of the test series which are receptacles for acids or other corrosive liquids, wholly or in part volatile, should be provided with ground glass caps. Fig. 53 represents a bottle of this pattern with the label corroded in by fluohydric acid. The mouths of all the test-bottles should have a flange in order to facilitate pouring. The last drop of liquid generally adhering to the lip can be arrested by touching it with the stopple, which catches and reconveys it to the bottle when returned to the mouth. As there is such frequent annoyance from the obstinate adhesion of

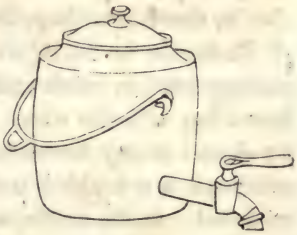
Fig. 53.

the stopper in the bottle containing *liquor potassæ*, it would be advisable to have one of the test-bottles constructed specially for holding that substance. The stopper should then be dispensed with, and the neck of the bottle made straight, so that when ground on the exterior to fit a cap like that in Fig. 53, the joint may be tight. A little care in preventing any dripping down the side when pouring from the bottle will always insure an easy removal of the cap, as may be necessary.

There are other laboratory uses, independent of the aforementioned, to which bottles are applicable. The wide-mouthed, when accurately stoppered and rendered air-tight in the mouth with a little lard or suet, are excellent substitutes for jars, for the reception and safe keeping of gases which are soluble in water or corrosive of mercury, and consequently cannot be collected over either.

Cleansing of Glassware.—When bottles or glassware are greasy, the aid of alkali or ashes is necessary for the removal of the dirt. In open vessels bran or sawdust, by their mechanical action, will cleanse the surface of grease. In either case hot water is a great assistant; and when the laboratory is not provided with a jack or generator, an iron or copper kettle, Fig. 54, fitted to the top of a stove or one of the openings in the top of the furnace, is a convenient vessel for furnishing a constant supply. The rinsing afterwards may be with cold water. A short twine brush, similar to that used by housewives for washing tea things, is an excellent assistant in cleansing operations, and there should be several of them about the laboratory. For alkali, lime as an example, which coats the sides, a little common muriatic acid is requisite. When the dirty matter is fixed and resists the purifying action of these two agents, and also of hot water, resort must be had to the use of small round pebbles, or very coarse sand, which, when agitated with a little water in the interior of the bottle, gradually removes the adherent dirt, and can then be rinsed out with clean water. Shot, though much used, are objectionable, as portions of the metal are apt to be left upon

Fig. 54.



the sides of the bottle, by abrasion of their surfaces. Carelessness in leaving behind one or more shot, which frequently secrete themselves in the crease at the bottom, may result in injury to the next contents of the bottle, if it be solvent of metal. The daily ablution of apparatus had better be performed at the close, and after the labors of the day, so that the advantage of the night may be obtained for draining and drying. Retorts and beaked vessels should be ranged on shelves with circular holes for the reception of their beaks. In this case as well also in that of open vessels, the mouths should always be placed downwards. When it is necessary to dry the cleansed vessel for immediate use, it may be well wiped with a towel exteriorly and then placed upon a moderately heated sand-bath, which will soon expel all internal moisture. Wide-mouthed vessels can be dried with a cloth. For cleansing test-tubes, a goose-feather or stick with a small sponge fastened to its lower end is very convenient; or, still better, a screw-ramrod.

The removal of corks from the interior of bottles is effected by an instrument consisting of four strands of iron wire, of about one foot length each, united together at one end, and at the other four extremities bent into an angular shape. Being elastic, there is no impediment to its passage through the mouth of the bottle, in the interior of which it is made, by a dexterous management, to catch and secure the cork, which can then be drawn out with the wire. This simple little instrument is to be purchased at any house-furnishing bazaar. A very convenient substitute is a doubled string; the loop thus formed, when introduced into the bottle, secures the cork and allows its easy extraction.

It not unfrequently happens with ground-stoppered bottles, in cases where certain substances form their contents, that the stopple adheres so firmly as to resist all efforts to remove it with the fingers. It is then necessary to tap it gently and alternately on each side with the handle of a spatula,—the spatula being held by the blade, and the bottle, by the top of its stopple, while the body rests on the table. In ordinary cases this process loosens the stopper, but if it fails, it then becomes necessary to carefully expand the neck over the flame of the small spirit-lamp, and in order that it may be uniform, the bottle must

be kept constantly revolving in a horizontal position. When sufficient warmth has been applied, a gentle tapping of the stopple, as above directed, effects its removal. After the neck of the bottle has cooled, it and the stopper must be washed and dried before the latter is returned to its place, otherwise it will soon become tightened again. The plan sometimes adopted of inserting the head of the stopper in a chink and then wrenching it out as it were by turning the bottle with the hand, is not advisable, as it endangers the safety of both the vessel and hand.

When the lamp is used, the motions must be dexterous and careful, so as to confine the heat to the neck of the bottle, for if it is allowed to reach the stopper also, the expansion of both being then equal, the removal of the former cannot be effected. The success of the effort depends upon a difference of temperature between the stopple and the neck which encloses it. Friction, induced by drawing a string constantly, and for a length of time, to and fro around the neck of the bottle, is sometimes substituted for the heat of a lamp.

When the cementing matter is a crystallized salt, hot water placed around the edges will loosen the stopper by dissolving the salt;—when it is metallic matter, hydrochloric acid is necessary, care being requisite that it does not injure the contents of the bottle. In some cases olive oil, similarly applied, is more effectual than either hot water or acid; and for resins, alcohol is most suitable.

These remarks are equally applicable to nearly all kinds of closed glass vessels. Broken glass and odd stoppers being often needed for various uses, should be preserved in a box for the purpose.

The Test-case.—The bottles of the test-case should be of white glass, entirely free from lead, and accurately fitted with ground stoppers. As they are constantly in use, it is preferable to etch their labels upon the glass. This is readily done by the operator himself, who has only to coat a limited space of the bottle (see Fig. 53) with melted wax, and after tracing thereon, with an iron style, the name and symbol of the reagent to be contained therein, to wet the marks with sulphuric acid, and then sprinkle on some finely-powdered fluoride of calcium (fluor spar). The fluohydric acid thus set free attacks the glass,

and rendering the latter opaque, makes the letters appear distinct, whilst the wax protects the other portion from its action, and when removed, presents the smooth surface of the glass. Care should be taken to avoid inhaling any of the escaping vapor, as it is highly dangerous in its effects upon the sysetm.

When paper labels are used they must be payed over with a thick coating of insoluble varnish, and written upon with incorrodible ink. The former consists of white of egg (strained), which is to be applied with a camel's hair pencil, and immediately coagulated by steam heat and then dried in an oven at about 212° F.: or it may be a solution of caoutchouc in benzole. The ink is made by dissolving one part of genuine asphaltum in four parts of oil of turpentine, and adding lampblack to render it properly consistent. The neatest method of marking the labels with the ink is by means of a small stamp and types. When the ink has dried, the varnish is to be applied as above, but preferably after the label has been pasted (with gum tragacanth) upon the bottle. The transparent film, hardened and rendered insoluble by heat, presents a firm resistance to strong acids, alkaline solutions, and other reagents; and, moreover, this kind of label is economical.

The test series should consist of ninety-one bottles, all of which are to be kept on the shelf-stand placed on the top of the table in the rear and resting against the wall, as shown at Fig. 38. The first ten bottles should be narrow-mouthed and of eight ounces capacity, to contain the following liquids:

1.	Sulphuric acid (pure),	SO_3.
2.	" " (common),	SO_3.
3.	Hydrochloric acid (pure),	HCl.
4.	" " (common),	HCl.
5.	Nitric acid (pure),	NO_5.
6.	" " (common),	NO_5.
7.	Aqua ammoniæ,	NH_4O.
8.	Hydrate of potassa, in solution,	KO.
9.	Carbonate of soda,	NaO,CO_2.
10.	" ammonia,	NH_4O,CO_2.

The next division of the series should comprise twelve narrow-mouth bottles, of six ounces capacity, and containing liquids, as follows:

11.	Acetate of lead (neutral),	$PbO,\overline{A}$.
12.	Chlorine water,	Cl.
13.	Absolute alcohol,	$C_4H_6O_2$.
14.	Ether,	C_4H_5O.
15.	Chloroform,	C_2HCl_3.
16.	Chloride of ammonium,	NH_4Cl.
17.	Oxalate of ammonia,	$NH_4O,\overline{O}$.
18.	Phosphate of soda,	$2NaO,PO_5,HO$.
19.	Chloride of barium,	BaCl.
20.	Sesquichloride of iron,	Fe_2Cl_3.
21.	Sulphate of magnesia,	MgO,SO_3.
22.	Succinate of ammonia,	$NH_4O,\overline{S}$

The third division should consist of sixteen four-ounce, narrow-mouth bottles, containing the following solutions:

23.	Sulphate of lime,	CaO,SO_3.
24.	Sulphite of soda,	NaO,SO_2.
25.	Acetic acid,	$\overline{A}(=C_4H_3O_3)$.
26.	Oxalic acid,	$\overline{O}(=C_2H_3,HO)$.
27.	Sulphide of ammonium,	NH_4S+HS.
28.	Acetate of soda,	$NaO,\overline{A}$.
29.	Nitrate of baryta,	BaO,NO_5.
30.	Baryta water,	$BaO+HO$.
31.	Chromate of potassa,	KaO, CrO_3.
32.	Sulphate of potassa,	KO,SO_3.
33.	Chloride of calcium,	CaCl.
34.	Bicarbonate of potassa,	$KO,2CO_2$.
35.	Nitrate of silver,	AgO,NO_5.
36.	Sulphate of copper,	CuO,SO_3.
37.	Protochloride of tin,	Sn,Cl.
38.	Sulphide of sodium,	NaS,HS.

The fourth division should consist of twelve narrow-mouth bottles of two ounces capacity, and containing liquids, as follows:

39.	Tartaric acid,	$\overline{T}(=C_8H_4O_{10})$.
40.	Hypermanganate of soda,	—
41.	Sulphate of alumina,	$Al_2O_3,3SO_3$.
42.	Tincture of galls,	—
43.	Bi-tartrate of potassa,	$KO,2\overline{T}+HO$.
44.	Protonitrate of mercury,	HgO,NO_5.
45.	Bichloride of mercury,	$HgCl_2$.
46.	Ferrocyanide of potassium,	2K,Cfy.
47.	Solution of indigo,	—
48.	Molybdate of ammonia,	?
49.	Sulpho-cyanide of potassium,	K,CyS_2.
50.	Carbazotic acid,	$\overline{P}$

The fifth division embraces ten reagents, contained in one-ounce, narrow-mouth bottles:

51.	Hydro-fluosilicić acid,	Si,Fl_2,HFl.
52.	Nitrate of nickel,	NiO,NO_5.
53.	Protonitrate of cobalt,	CoO,NO_5.
54.	Arseniate of ammonia,	$3NH_4O,AsO_5$.
55.	Sodio-protochloride of palladium,	—
56.	Bichloride of platinum,	$PtCl_2$.
57.	Terchloride of gold,	$AuCl_3$.
58.	Hydrate of soda,	NaO.
59.	Antimoniate of potassa,	KO,SbO_5.
60.	Cyanide of mercury,	$HgCy$.

The sixth and succeeding divisions comprise solid matters which require wide-mouth bottles. The first ten bottles should be of four-ounce capacity.

61.	Carbonate of lime,	CaO,CO_2.
62.	" baryta,	BaO,CO_2.
63.	Sulphate of lead,	PbO,SO_3.
64.	Sulphuret of iron,	FeS.
65.	Bisulphate of potassa,	$KO,2SO_3$.
66.	Dry carbonate of soda,	NaO,CO_2.
67.	Mixed carbonate of soda and potassa (dry),	NaO,CO_2+KO,CO_2.
68.	Pulverized charcoal,	C.
69.	Granulated zinc,	Zn.
70.	Nitrate of potassa,	KO,NO_5.

The seventh division should comprise nine two-ounce bottles.

71.	Fluoride of barium,	$BaFl$.
72.	Chlorate of potassa,	KO,ClO_5.
73.	Copper wire clippings,	Cu.
74.	Iron wire clippings,	Fe.
75.	Cyanide of potassium,	KCy.
76.	Dry carbonate of potassa,	KO,CO_2.
77.	Starch paste,	—
78.	Hydrated teroxide of bismuth,	BiO_3,HO.
79.	Oxide of lead,	PbO.

The eighth division should consist of twelve one-ounce bottles.

80.	Iodide of potassium,	KI.
81.	Ferri-cyanide of potassium,	$3K,2Cfy$.
82.	Biborate of soda,	$NaO,2BO_3$.
83.	Oxide of barium,	BaO,HO.
84.	Nitro-prusside of sodium,	Fe_2Cy_5,NO_2,Na_2+4HO.
85.	Peroxide of mercury,	HgO_2.
86.	Phosphate of soda and ammonia,	$HO,NH_4O,NaOPO_5+8HO$.

87. Blue litmus paper, ... —
88. Red " " . . . . . —
89. Turmeric " . . . . . —
90. Georgina " . . . . . —
91. Lead " . . . . . —

A leaden or gutta-percha bottle, with a closely fitting stopper, and of two ounces capacity, for the fluohydric (HF) acid, completes the series.

All these bottles should be made heavy, for if too thin, being so frequently handled, they are liable to be broken. Of the preceding numbers, 1, 2, 3, 4, 5, 6, 7, 8, 14, 27, should be furnished with ground glass caps, as shown by Fig. 53. No. 35 must be of dark glass, or else covered exteriorly with black paper. Nos. 87, 88, 89, 90, 91, should always be accompanied with a pair of pincers with platinum points, similar to those used in blowpipe operations, as the test papers should never be handled with the fingers. The bottles for alcohol ($C_4H_6O_2$) and distilled water (HO) may be of common green glass, narrow-mouthed, and quart-size. They are fitted with double tubes so as to admit the air gradually, and thus promote a gentle flow of the liquid from them, in the act of pouring; and are designed as conveniences to the operating-table, for supplying small quantities of their contents to test tubes and narrow-mouthed vessels without the aid of a funnel. Fig. 55 shows their form and arrangement.

A piece of bright copper, and one of iron, are also frequently needed as reagents.

All of the forenamed reagents must be chemically pure, as also the water used in making solutions of them.

Fig. 55.

The reservoir for distilled water should be a close jar of blue stoneware or white iron stone china, the glazing of which is free from lead; and it must have a glass cock near the bottom through which to draw off supplies for use, as may be required.

Besides the reagents, a small stock of which should always be kept in reserve on the shelves of the cupboard, there is required a general assortment of drugs and chemicals in

limited quantity. The coarser and cheaper articles of this stock should preferably be purchased from the dealers, but it is advisable for the operator to prepare the costlier ones for himself, not only on the score of economy, but also because of the practice which he will acquire in the manipulations of various processes.

There remain but few points to be remarked upon before closing our chapters upon the laboratory. We have already enjoined upon the experimenter great cleanliness, and we now repeat the injunction. The hands should always be free from dirt, and invariably washed with castile or palm soap before going to meals. This precaution is absolutely necessary on account of health, for otherwise, in working with deleterious matters, the minute particles which secrete themselves under and around the finger nails, may be conveyed into the system, and thereto work an injury. So, also, when engaged at one time upon several operations of a different nature, it is necessary to rinse the hands in passing from the management of one to that of another of them. For this purpose, the hydrant or reservoir with its adjoining hand-towel, Fig. 30, is very convenient.

To protect the person from dirt, the operator should provide himself with a suitable costume. A long wrapper of linsey or baize for winter, and of Holland linen for summer, is very suitable. A light cap of some cheap material, is a good shield to the hair against the bad effects of dust and vapor.

In all investigations, the practice of working upon small quantities will lead to habits of nice and delicate manipulation. Besides, it is easier, less costly and fatiguing to manage a small portion of any substance.

There are three blank books requisite in every laboratory. The first may be called the *Laboratory Record*, as it is designed to contain full notes of the progress of every experiment and operation going on in the laboratory. In this way, a large store of valuable facts is preserved for future reference. The second book is the *Record of Analyses*, in which are transcribed the results of analyses of such substances as may have undergone examination in the laboratory. The mode of analysis may also be included. This record is also very useful for future reference. The other book is an "*Index rerum*," after the plan of the Rev.

J. Todd, author of the Student's Manual. As it is impossible to retain all that one reads, and much being valuable, some other means more practicable and less laborious than copying out extracts must be adopted for preserving its remembrance. Mr. Todd recommends the habit of making an *index rerum* in reading. This book consists of several quires of blank sheets, letter form, and is alphabetically classified, so as to exhibit at a glance, the name of the book and the number of the page treating of the subject, the synopsis of which is recorded under its appropriate letter and heading. Such a digest of journals and books, though very meagre, will still present their notable points, and prove an all-sufficient key, when making researches in the future upon any subject about which it is desired to have all existing information. Always, as Mr. Todd directs, have your index at hand when reading book, journal, pamphlet, or newspaper; and "when you meet with anything of interest, note it down, the subject, the book, the volume, and the page; and make your index according to subjects as much as possible, selecting that word for the margin which conveys the best idea of the subject," so that there may be no difficulty in finding the original place when it is necessary to refer to it. The following are a few examples of the manner in which the digests should be recorded:—

A ACIDS FATTY.	New theory of their constitution, by James C. Booth, *Journal of the Franklin Institute* for 1848.
G GUTTA-PERCHA.	Investigation of the properties of, by M. Payen, *Chem. Gaz.* 1852, *p.* 176.
S SILICIUM.	New mode of making, with Silica and Sodium, by St. Clair Deville, *Comptes Rendus*, 1855, *p.* 1053.

There are many other minutiæ that might be mentioned, but for want of room for more important matter; and so we leave them to be suggested by experience.

Habits of industry, close observation, and neatness, are indispensable to the acquisition of skill in manipulating, and without them it will be difficult to become an accurate chemist.

The laboratory which we have described, is well appointed for every branch of research. Many of the implements enumerated

may be dispensed with for ordinary operations, but they are requisite for a complete arrangement, which, as given in the preceding chapters, is not at all extravagant. Moreover, with a little extra industry, the operator can soon realize the outlay for all conveniences, in the manufacture and sale of such pure chemicals as may be in demand. We have provided him with every appliance for the purpose, so that his self-improvement may be attended also with pecuniary profit.

Where the means are limited, it is better that the purchase of apparatus should be gradual, commencing with those pieces which are of most general use. This course judiciously carried out, will in time secure a well-stored laboratory. All stock and apparatus can be bought from the manufacturer, or importer, at very little over one-half the dealer's prices, for the same articles.

CHAPTER IV.

DIVISION OF SUBSTANCES.

THIS operation is a mechanical process, by which the surface and points of contact of solid bodies are multiplied; thus diminishing, in a high degree, the opposing force of cohesion, and, consequently, by promoting greater access to its particles, enabling the more ready and rapid action of reagents upon solid matter.

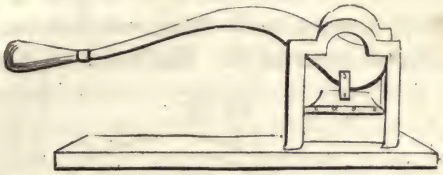
The means by which the division of solid matters is accomplished are manifold, and vary with the nature of the substance to be reduced; some bodies being pulverizable by almost any of the processes, while others again require a particular method for their reduction. The different modes of operating may be classified as follows:—

1st. *Slicing.*—This process applies to fibrous matters, and is practised with a spring lever-knife, similar to that used by tobacconists for cutting tobacco, and shown by Fig. 56.

Being thus reduced to thin slices, the substance is in better form for maceration, &c.; and, moreover, admits of readier desic-

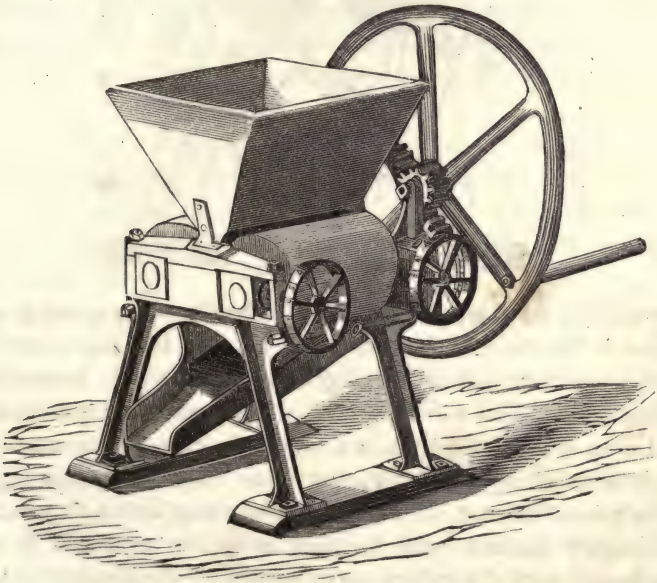
cation, a necessary process when it is required to be further reduced under the pestle, or by being grated on a coarse rasp.

Fig. 56.



This mode of pulverization by rasping, though particularly applicable to fibrous substances, such as fresh roots and the like, is sometimes used for metals and hard matters. In the latter case, the files must have finer and sharper teeth, and in both instances be perfectly clean, and free from grease and dust.

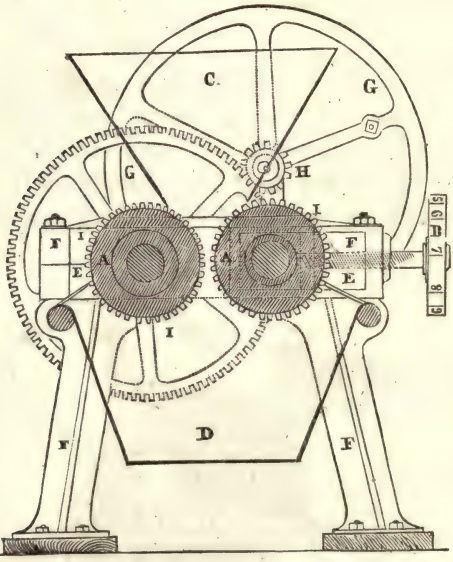
Fig. 57.



2d. *Crushing.*—Fresh roots and juicy vegetable matters of a tough, stalky, and fibrous nature, which are not required to be reduced under the knife, may be better prepared for the action of solvents or the press, by being crushed under the pestle in a common mortar. As this mode, however, is very tedious, and

inapplicable even to moderately large quantities, it is best to use a machine which has been devised for the purpose by Coffey. It is shown, in section and elevation, by Figs. 57, 58, and consists a cast iron frame F F, on which is set a pair of hard wooden rollers revolving towards each other, and fed from a hopper C with the material to be crushed. The latter, as it passes through

Fig. 58.



the rollers, falls into a receiver D beneath. The gearing comprises a fly-wheel G, a spur-wheel H, and the cog-wheels I I. Being put in motion by turning the handle, which, however, requires considerable power, the rollers draw the material through, and drop it in the receiver in a thorough state of contusion. It must be mentioned, however, that some tough substances require to be passed through the rollers several times before they become thoroughly crushed; and for such cases, the wheels B B, communicating with the rollers, serve to regulate the distance between the two, as may be necessary for widening it at the first step, and closing at the final operation. In this way, the hard as well as the soft parts of the substance become uniformly crushed; and, the crushed matter may be pressed, without passing any suspended particles of woody fibre with the juice.

3d. *Pulverization.*—In order to obtain a minute division of the denser substances, whose particles are very cohesive, resort must be had to the pestle and mortar. The material of this apparatus varies with the nature of the substance to be powdered. To prevent errors, corrosive or caustic matter should never be pulverized in metallic mortars, else by a solution of a portion, or contamination with abraded particles, unavoidable confusion will ensue. The resistant nature of the material of the mortar must be proportional to the hardness of the body to be operated upon. For the harder insoluble substances, those of iron, or steel, are generally used. For the less dense and more pulverizable bodies, especially those which are acid, or corrosive, porcelain, wedgwood, or glass, is the proper material. Marble, being readily attacked by acids, mortars of that material are only used for reducing those inert substances which are readily comminuted merely by trituration, such as chalk, neutral salts, &c. This material, as well as glass, is well replaced by porcelain or wedgwood, which are stronger, and otherwise much less objectionable. There should be an assorted series of mortars for laboratory purposes.

The large iron mortar has its position in the furnace-room, and is permanently and firmly fitted upon an upright block of hard wood, Fig. 59, in some convenient place, for general use, in pounding ores, metals, and coarser substances. The pestle of this, as of all other mortars, should invariably be of one piece and of the same material as the mortar; because, when the lower part is fitted to a handle, it is apt to become loosened and drop off particles of the cement with which it is fastened, to the injury of the contents of the mortar. The handle or upper portion must afford convenient space for grasping, and the base or lower portion, roughened on its face by use of sand, should diverge to a diameter of about one-fourth of that of the mouth of the mortar. Fig. 60 exhibits a mortar of proper form and proportionate thickness as to its different parts. Its interior form is nearly that of the butt end of an egg, so as to promote a constant contact of the matters under process, with the rotating pestle. To prevent the ejection of particles of matter or the escape of dust, and consequent inconvenience to the operator, as the case may be, the mortar should be provided with a sheep-skin conical coverlet,

with a hole in its centre for the passage of the pestle, which is to be fastened around its rim and over its mouth, with a string. Circular pasteboard and wooden covers, of sizes corresponding with the mortars and with a hole in their centres, are often substituted for the conical coverlet. The operator should always stand with his back to a current of air; and to further guard against the unpleasant or deleterious effects of the fine dusty particles which may arise from the mortar, he can moisten

Fig. 59.

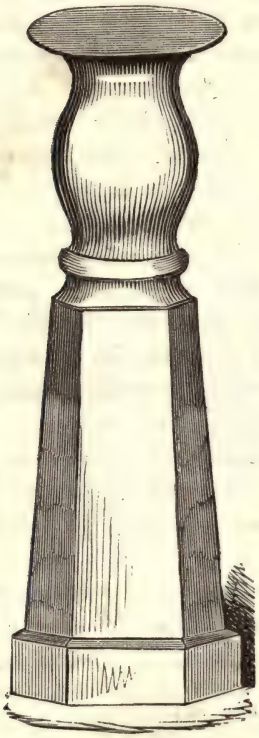
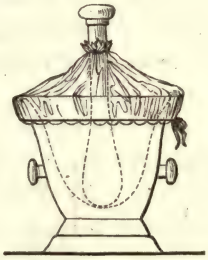


Fig. 60.



its contents with a little water, provided that liquid is without action upon the substance. Exposure to warmth, for the evaporation of the water, will restore the matter to its original dryness.

All substances formed of an organic tissue should be previously dried, so as to afford greater facility in their pulverization, but care must be observed to avoid a heat sufficiently high to injure their properties. A previous reduction of ores, and coarse hard substances into lump, by concussion with a hammer upon an anvil, and of roots and the like into slices or bits with a common knife or lever-cutter (Fig. 56), are preliminary processes which greatly facilitate their pulverization. The substance to be struck upon the anvil should be previously wrapped in strong brown paper.

Silicious stones pulverize much more readily after having been

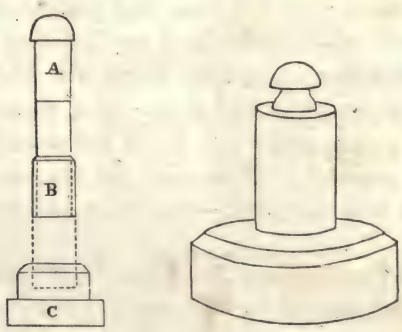
heated to redness in a crucible, and in that state projected into cold water. This increased friability is occasioned by the unequal cooling of the mass.

Metals, alloys, and the like, which are difficultly pulverizable whilst cold, may also be readily crushed when heated to redness.

When it is required to reduce the substance into small fragments only, it can be broken down by a succession of blows with the pestle. If the substance is very hard, the force of the arm should be added to the descending weight of the pestle, so as to impart power to the blow. A subsequent circular grinding motion of the pestle, continued for a length of time, will further reduce these fragments to fine powder, and consequently this movement must be avoided when only a coarse comminution is desired. The mortar must always rest upon a solid foundation, and during the operation of pounding should be occasionally shaken, in order that the coarser particles which mount to the sides may be forced back to the centre of the mortar, so as to receive the full effects of the descending pestle, which should never be allowed to strike the sides of the mortar. If the substance is to be reduced to a fine powder, the process is greatly facilitated by operating upon only a small portion at a time, as the pestle is less liable to become clogged.

In the analysis of rare minerals, especially those which are

Fig. 61.



very hard, the reduction is effected in a small mortar of hardened steel. This apparatus, shown by Fig. 61, consists of three separable pieces, each of which is smoothly turned, so as to present

an even surface exteriorly and interiorly. C is the base piece, into the cavity of which the cylinder B fits somewhat loosely. It is this cylinder which receives the mineral to be reduced. Sliding into it is the exactly fitting pestle A, which being struck successively with a hammer, crushes the mineral to powder without waste of any of its particles by ejection.

When the powder thus obtained is not yet sufficiently fine for analysis, it must be transferred to an *agate* mortar, and rubbed with the pestle until reduced to an impalpable state. The pestle and mortar are of the same material, the hardness and smoothness of which render it particularly applicable for the purpose. The motion of the pestle should always be circular, otherwise a perpendicular blow may endanger the safety of the mortar, especially if it has a fissure, as is often the case, running through it. The given weight of the mineral for analysis must always be estimated after pulverization;—never previously, lest a loss by ejection, or adhesion to the mortar or spatula, may lead to inexact results. Fig. 62 exhibits an agate mortar, which can be purchased of sizes varying from 1 to 6 inches in diameter. One of about 3½ inches width will be most useful. It should be selected as free from indentations, fissures, or cavities as possible, for these faults not only impair the durability of the mortar, but render its cleansing very difficult. An excellent plan of removing tenaciously adhering matter from the sides or bottom of a mortar, is to rub them with pumice-stone and water.

Fig. 62.

4th. *Trituration.*—This mode of manipulating with the pestle is application to those substances which are friable, and fall to powder by being merely rubbed up by a circular or grinding motion of the pestle, and which would soften and become obstinate by being pounded. Chalk and the like, and most of the salts, are in the first category;—the resins and gum-resins in the second.

Sand is added to facilitate the reduction of resins and similar substances, which cake under the pestle, only when they are intended for maceration or solution. Under other circumstances, the medium would be an adulterant on account of the impossibility of separating it.

The proper material for a mortar for this purpose is white

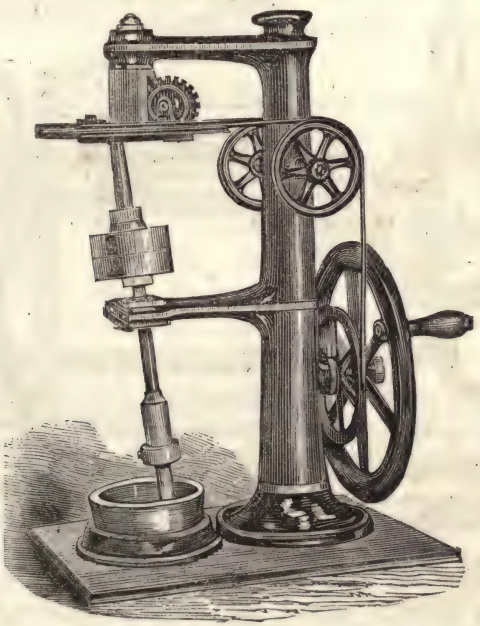
wedgwood, of form as shown by Fig. 63. Berlin porcelain mortars, glazed outside and biscuit internally, with broad-butted, solid pestles, as shown at Fig. 64, are neat and convenient implements, but less available for general purposes than those of

Fig. 63.

Fig. 64.

wedgwood, which are stronger, more durable, and will stand harder blows. These are purchased by the diametrical inch, and the most convenient size is 6 to 8 inches width at the mouth. It will be well also to have a smaller one of the same material, say of 2 inches diameter at the top.

Fig. 65.



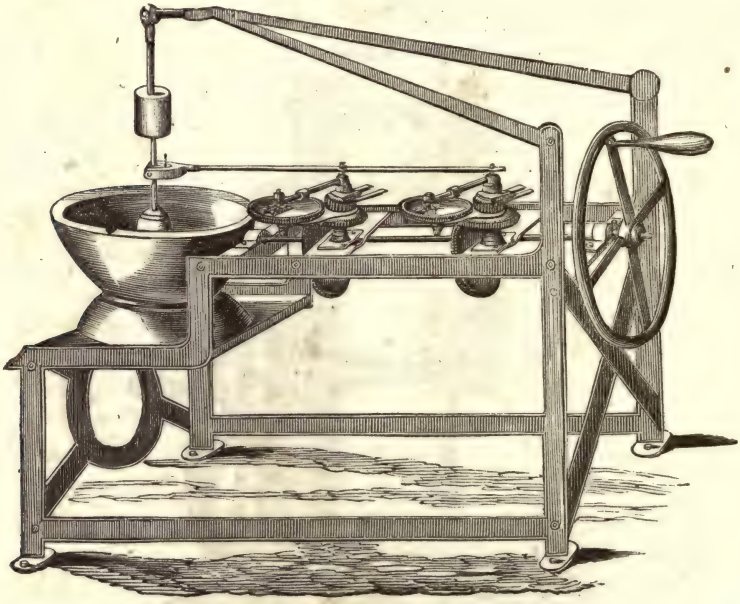
Hewitt proposes to reduce the amount of labor and time required in the use of mortars, by the substitution of machinery ;

and to this end, has presented an ingenious invention, Fig. 65, which imitates exactly the rotating motion given to the pestle by the hand. The weight of the pestle of this machine is 12 to 14 pounds, and its gearing and action are intelligibly expressed by the drawing.

It is said to require very little power, and that only from the hand. Aloes, cantharides, and similar substances, are reduced to fine powder, by its means, with great promptness; moreover, it moves noiselessly, and does not scatter dust.

Another machine, of similar purport, but of more extended application than the above, both as regards the varieties of substances and the quantities which may be operated upon, is that known as Goodall's grinding and levigating apparatus, shown by Fig. 66. In this, as in the former invention, the pestle acts

Fig. 66.



from a motion similar to that imparted by the hand; and as it traverses a different surface each rotation, no scrapers are required to keep the powder constantly under action. Steam-power increases the efficiency of the apparatus; but it acts readily with hand-power, even upon the hardest substances.

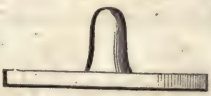
A weighted lever secures the pestle at the top, and the gearing from which it derives motion is driven by a bevel-toothed cog-wheel on the main driving-shaft, which is provided with a winch-handle. The mortar is placed in front, to be wholly out of the way of falling dust and dirt from the moving wheels and other parts of the machinery.

The pestle being attached to the driving-shaft by a screw can be removed as may be required.

5th. *Porphyrization.*—This mode of pulverizing, only employed when it is required to reduce the powder to the greatest fineness, takes its name from that of the material of the vessels in which it is practised. A small porphyry mortar, hemispherical interiorly, or, preferably, a slab and muller, is the apparatus employed. Flint, and even glass, which are equally as hard as porphyry, form an economical substitute for that material. It is highly important that the material of the apparatus shall be less easily abraded than the substance being ground; for if too soft, the latter becomes contaminated with the particles which are rubbed off, and, hence, in exact investigations, inaccuracy is occasioned.

Porphyrization is generally effected by rubbing the coarse powder between a flat slab and muller, until reduced to an impalpable state. The circular motion of the muller disperses the powder over the slab, rendering it frequently necessary to collect it together in the centre with a spatula, so as to keep it uniformly under the action of the muller. The spatula may be of horn or steel, but is better when of platinum. Fig. 67 exhibits a slab and muller. When the substance under operation is unalterable by water, it may be moistened with that liquid, which, by converting it into a paste, facilitates its reduction, and prevents any waste by the escape of dusty particles. The powdered paste is easily dried by being dropped in dots upon a porcelain plate and exposed to warmth. Those matters which are soluble in or alterable by water, must be porphyrized in a dry state.

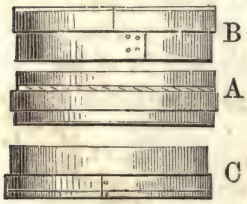
Fig. 67.



6th. *Sifting.*—The impossibility of reducing the whole of a substance at once to a uniform state of fineness by any of the preceding processes, renders necessary an occasional separation,

during the progress of pulverization, of the more comminuted portions from the grosser particles. This is effected by means of a sieve, of which there should be several in the laboratory. A wooden cylinder of about four inches depth, with an accompanying ring of the same materials, constitutes the frame, over which can be stretched a cloth of any required fineness. For coarser articles, fine brass wire is the best material for the cloth, but when the powder is to be impalpable, bolting cloth (raw silk), or gauze is requisite. Sieves are also covered with hair-cloth, buckram, book-muslin, and iron wire of different sized meshes, each of which has its appropriate application. The metallic sieves should have their cloths permanently fitted to them. For all the rest, two frames, as above described, one of much larger dimensions than the other, will serve; as it is only necessary to remove the ring when it is desired to substitute one kind of covering for another. The sieves of cloth, of graduated fineness, can be kept in some secure place, and withdrawn as wanted, and thus we have the economical means of possessing a full suite of sieves from the metallic wire, through all the grades of fineness up to the closest wrought bolting-cloth. The form of a sieve is shown at A, Fig. 68. After the separation of the finer portions by the sieve, the coarser particles are again subjected to grinding and sieving as often as is necessary to convert the whole into the requisite state of uniform fineness. Horn-scoops, or porcelain spoons, or ladles, are the proper implements for transferring the contents of the mortar to the sieve. In some cases, a stiff pasteboard card, being more pliable, is a convenient substitute. The use of the hand, for this purpose, should always be avoided as a slovenly practice. A platinum, horn or bone, or, less preferably, steel spatula may, be used to detach the particles adherent to the sides of the mortar. To prevent inconvenience or injury to the operator (who, both in powdering and sieving, should always stand with his back to a current of air), from particles of dust or acrid poisonous matter, as well also to avoid waste, the sieve should be fitted with a top and bottom covering, as shown at B and C, in Fig. 68, the upper

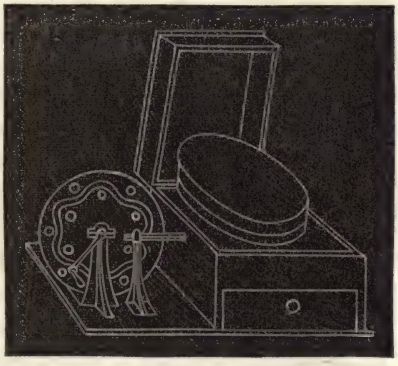
Fig. 68.



of which arrests the escape of the light dust into the air, and the lower receives that portion which passes through the cloth. These covers are headed with parchment or calf-skin, and the three divisions, when joined together, form what is called a drum or box-sieve. The powder is made to pass through the meshes by gently agitating the sieve between the hands. A rough jarring motion will force through some of the coarser particles, and thus destroy the uniformity of the powder; and hence the common practice of tapping it frequently against the side of the mortar should be abandoned, unless the state of fineness is immaterial, as a regular and gentle horizontal motion is indispensable to insure uniformity and impalpability. Some substances, however, as magnesia, &c., which obstruct the pores of the cloth, must be forced through in this manner, and even, if necessary, by a circular motion of the fingers over the interior surface of the cloth. This manipulation frees the meshes of the cloth from obstructions, but it must be carefully done, otherwise the safety of the cloth will be endangered. A sieve is also useful for the admixture of powders of uniform fineness.

The importance of restricting the sieve to a horizontal motion induced Mr. Harris, of Philadelphia, to invent a special arrangement (Fig. 69) for the purpose. The sieve is of the usual form, but requires to be enclosed in a box. Motion is communicated by means of a wheel, an axle, and a crank, with six eccentric depressions and elevations upon one of its sides. There are two upright standards fastened to the same footboard, one of which supports the wheel and the other a horizontal bar of iron passing through the side of the box and attached by the other end to the side of the sieve, resting on horizontal ledges in the interior of the box. On turning the crank, the horizontal bar will, in its motion, necessarily follow the sinuosities of the wheel, and as

Fig. 69.



a consequence draw the sieve backwards and forwards. Very fine powders are obtained by enclosing the powdered matters in a bag of close texture and shaking it within a tin canister, which catches and retains the dust as it passes through the meshes.

7th. *Levigation*—Is that mode of mechanical reduction which is practised by first rubbing the substance into a smooth paste, and then separating the finer from the coarser portions by agitating the triturated matters with water. After a sufficient repose, the grosser and heavier portions subside, leaving the lighter particles still suspended in the water. This water, after decantation, gives a second deposit of an increased state of fineness. The third or fourth decantation yields the powder of impalpable fineness. The time of repose between the decantations, unless great impalpability is required, should be limited, and only long enough to allow the deposition of the heavier portions. The coarse precipitates are collected together, a second and as many more times as necessary, rubbed up as before, and treated with water, until all the lighter portions have been separated. This process applies only to substances unalterable by water. When uniformity of fineness is not all-important, one washing even suffices, and can be accomplished in the mortar without the use of glasses. Alternate poundings and washings will eventually reduce and remove the whole contents of the mortar. In washing over gold and other metallic ores, where only the heavier portions are to be reserved, the water may be allowed to flow directly into the mortar, which being held in an inclined position, permits its exit, together with the fine dusty portions which are kept in suspension by trituration with the pestle.

This process of levigation is founded upon the different specific gravities of the coarse and fine bruised matters, and is, therefore, not only applicable for the separation of the particles of homogeneous matters, but also of equally fine matters of unequal densities. In the latter case it takes the name of *elutriation.*

All minerals for analysis, which have to undergo ignition with alkalies, should be previously levigated, in order that decomposition may be complete; for if the powder is not uniform the larger particles will escape decomposition.

Pulverization in this manner, by uniformly comminuting the particles, promotes their equal expansion and the escape of con-

tained moisture, and thus prevents the decrepitation of substances when heated.

The deposited powder must always be dried, by exposure, previous to subjecting it to any other process.

8th. *Reduction by Granulation.*—The reduction of metals to granules is effected by fusing them in a crucible, and pouring the melted matter, from an elevation, in a thin stream, very gradually, into a large bulk of cold water which must be kept, during the process, in constant agitation with a stirrer. The fineness of the resultant granules is proportional to the slowness with which the fused metal was poured into the water. It is more convenient to transfer the metal from the crucible into a ladle, and project it into the water from that more handy vessel, which enables a frequent change of the position of the descending stream, and thus prevents the formation of clots instead of smaller and more solid granules. The fusion of zinc for granulation must be in a covered crucible, otherwise it becomes oxidized whilst hot, and partially sublimes by exposure in an open vessel. Zinc and tin may also be finely divided by heating them a little above their melting-points and rubbing them in a previously heated iron mortar, until the mass congeals into powder. Iron is brought to powder mechanically by the file, and chemically by reduction in an atmosphere of hydrogen gas.

The process of fusing metals and then agitating the melted matter in a wooden box until cool, reduces them to a state of minute division, but at the same time promotes their oxidation. For general purposes, however, it is not objectionable, and the particles of charred wood with which it becomes mixed can be separated by elutriation. The sides of the box are generally well chalked, to prevent any adherence of the metal;—and this also is separable by elutriation.

REDUCTION BY CHEMICAL MEANS.

9th. *Division by Intermedia.*—This mode is both mechanical and chemical, and applies particularly to the noble metals, in foil, which are difficult of pulverization. Honey, sugar, salts, &c., are the most usual media. By binding the particles together, it assists their minute division, and prevents their escape from

the mortar. The addition of boiling water solves out the medium, without action upon the metallic powder, which then only requires to be thrown upon a filter and dried.

Phosphorus may be finely divided by fusing it, with alcohol, over a water-bath, and shaking the contents of the flask until thoroughly cooled. The phosphorus subsides at the bottom in pulverulent form. Camphor, which is obstinate under the pestle, readily yields to its power when mixed with a few drops of alcohol or ether, to destroy its elasticity.

Silica may be precipitated from lime-glass in a pulverulent form, by the digestion of that compound with hydrochloric acid. Silver is obtained in a powder by the decomposition of its nitric solution with a metallic copper rod; or of its chloride by metallic zinc. Proto-sulphate of iron throws down gold, in a finely-divided state, from the solution of its chloride; and spongy platinum is formed by the dull ignition of the ammonia-chloride of that metal. These are instances of chemical division by purely chemical means. The extreme state of division thus obtained by the solution and precipitation of a solid body, (a chemico-mechanical process) cannot be effected by any purely mechanical power.

The sublimation of sulphur into flowers, as also of calomel into fine powder by means of large airy chambers, are instances of comminution by chemico-mechanical means;—the vaporized particles being prevented from reunion, at the moment of solidification, by the intervention of the cold air. So, likewise, in cases of division by hydro-sublimation, the intervention of aqueous vapor prevents the conjunction of the vaporized molecules. Dr. Joslin (*Silliman's Journal*, p. 48, vol. v) treats of this subject in extenso.

CHAPTER V.

THE BALANCE.

A BALANCE may be considered the most indispensable implement of the laboratory, as affording the only means by which the chemist can accurately estimate the quantitative results of his in-

vestigations. The construction of this instrument for determining the relative *weight* (*the measure of the force by which any body, or a given portion of it, gravitates towards the earth*) of substances, is based upon certain mechanical principles, of which we proceed to give a brief explanation.

A balance consists of an upright shaft, supporting, by its immediate centre, an inflexible *lever* or beam, with arms of equal length and symmetry, to each of which is suspended a dish for the reception of the weights (the *power*), and the body to be weighed (the *resistance*). Of the three axes of the beam, that in the middle is the *fulcrum* or centre of motion, upon which it turns in a vertical plane. The other two axes are at the extremities of the arms. All three axes should be at right angles to the plane of motion, and parallel to each other.

The requisite conditions of a good balance.—One of the chief conditions of an accurate balance is a free suspension of the beam, in order that it may vibrate with the least possible friction. The two arms must also be precisely equal, so that when empty, or the weight in each dish is uniform, there will be a perfect equilibrium. The *sensibility* of a balance is proportional to the angle formed by the beam with the horizon, when a slightly greater weight is placed in one dish than in the other. This sensibility depends on the position of the centre of gravity of the beam with reference to the line of suspension; this centre must be below that line, but as near as possible to it, so that the slightest weight will cause the beam to oscillate freely.

As the inertia and friction are proportional to the weight of the beam, it must be made of material entirely free from imperfections, and so as to combine strength and inflexibility with lightness. It may be of solid steel, rolled brass, German silver, or of a malleable alloy of copper and tin, but not of cast metal of any kind. The upright support can be of brass, and the dishes and suspension frames of platinum.

The sensibility of the balance increases with the length of the arms, which should, however, have a certain limit, and be as nearly uniform as possible in every respect. When, through unskilful construction, the length of one arm is slightly greater than that of the other, in order to avoid the error in weighing which this defect would occasion, the body to be weighed is

placed in one pan, and counterbalanced by weights in the other. The amount of weight required to restore the equilibrium, after the withdrawal of the substance, is its correct weight.

In order to avoid friction, the parts of contact should be as few as possible, and the knife edges must be made of highly polished, hardened steel, and the beds or *planes* upon which they rest, of agate or flint. The accuracy of the balance will depend greatly upon the skill and precision with which these portions and the beam are elaborated.

A good balance, with 1 to 2000 grains on each dish, should be sensitive to the one or two thousandth of a grain.

The Mint Balance.—"To obtain the greatest degree of uniform precision, it is requisite that the beam should be lifted from a state of rest, in a perfectly level position, and that the stirrups should be lifted simultaneously with their loads from their rests or supports; also that the oscillations of the stirrups should be prevented or checked at the earliest moment; and, finally, that the whole system should be left at liberty with delicacy and exactitude, so as to remain in equilibrium, or vibrate as the case may be."

"To command the above conditions, the beam should be supported upon cones at each extremity, adjusted level with each other, from which it is lifted, by a plane (and not a portion of a hollow cylinder, as is usual), which rises under its centre knife-edge, and to which it is returned by its depression, the cones guiding the beam to the same position exactly from which it was elevated.

"The stirrups, in like manner, should hang upon hollow cones or V's, so as to be taken up from, and returned invariably to the same position.

"The beam should rest upon its cones, and the stirrups should be supported by their V's at such heights as to relieve entirely the knife-edges, with a sufficient space between them and their respective planes to permit inspection and wiping, when it may be needed. This construction admits of the placing of the weights, &c., and guards the knife-edges from the consequences of displacement during use.

"The beam should be raised by the elevation of the centre plane, subsequently lifting with it the stirrups with their weights and load, and all oscillation checked by platforms placed in the

table under the centre of the stirrups, which should be made to rise simultaneously, and should be counter-weighed to the requisite delicacy.

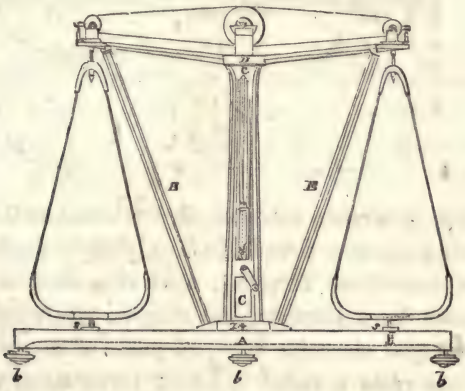
"The descent of these platforms, effected by the pressure of a finger on a lever conveniently placed, will leave the stirrups, &c., at liberty to vibrate, or bring the beam to a horizontal position, at the will of the operator, being a convenient, certain, and rapid method of manipulating, not equalled by any other arrangement, and, in fact, essential to a well-constructed balance."

These essential qualities of an accurate balance for the more delicate operations of the laboratory are comprised in that form of balance used in the United States Mint, and which "combines all the important advantages heretofore known with such improvements as have been the growth of their own experience."

This form of balance is best adapted for exact weighings of large quantities of matter; and therefore should constitute the larger weighing apparatus of the laboratory.

Fig. 70 gives a front view of it. We take our description from the *Journal of the Franklin Institute*, vol. xiv.

Fig. 70.



A table, marked A, is furnished with levelling screws upon the front and back edge, and at each end, marked *b*. In Fig. 72, which exhibits different views of all the parts, the levelling screws are marked *b*, and their positions in the table (the view of the under side of which is given) are marked *c*.

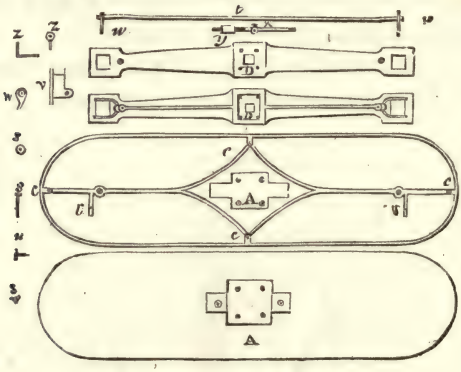
The balance is intended to be placed upon a counter, or any

other firm support, and the table levelled by means of the screws last described, its true position being indicated by a plumb-line and weight occupying the rear opening in the column (Fig. 72, C); the plumb-line and weight being marked *d*.

The column, marked C, Figs. 70, 72, contains the lifting apparatus, and supports the cap-plate, marked D. The cap-plate guides the lifting apparatus, and supports the V's, or hollow cones, for the stirrups, and is strengthened and stayed by braces, marked E; the section of which braces is cruciform, with circular ends, for firm bearing upon the plate and base of the column, to which they are secured by screws.

Figs. 71, 72, exhibit upper and under views of the table, column, plate, &c., also upper and lower end views of the column, showing the means of its attachment to the table and cap-plate.

Fig. 71.



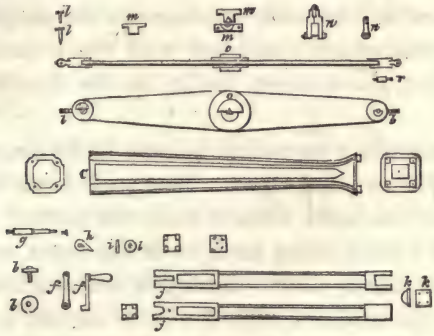
The lifting apparatus consists of a winch-handle, marked *f*, Fig. 72, fitting upon a round shaft *g*, with a feather, so as to admit of its convenient removal; upon this shaft is fitted a cam *h*, also secured by a feather; the cam is carefully constructed, so as to give equal elevation to equal parts of its revolution; and upon the cam rests a roller *i*, which turns upon a pin in the frame *j*, intended to reduce friction, and give facility in raising the beam with its load.

The lifting frame *j*, is forked cross-wise, so as to straddle the shaft and accommodate the cam and roller, at the same time that it allows the necessary vertical motion, without the possibility of being displaced; all of which is exhibited in the two views of the

lifting frame marked *j*, which is also accompanied by sections in proximity to the parts which they are intended to explain.

The handle is so placed as to be on the left when the beam is down and at rest, and to the right when the beam is raised, in the act of weighing, and makes, together with the cam, more than three-fourths of a revolution, the cam having a very slight depression upon its upper, or highest point, into which the roller falls, maintaining it in its position when the beam is raised. It is then extended beyond the centre of the roller, so as to be stopped at the limit of motion, as exhibited *h*, Fig. 72.

Fig. 72.



The lifting-frame is forked at the top for the accommodation of the beam. Upon it rests the plane, the top and side view of which are marked *k*, for the support of the centre knife-edge, secured to the frame by screws. In balances of ordinary construction, this plane may be made of hardened cast-steel; in finer instruments, of bronze, or brass, with an inserted block of polished agate, secured by fusible metal or cement.

The position of the handle, lifting-frame, &c., are exhibited with sufficient clearness in the front view, Fig. 70.

The cap-plate, views of the upper and under sides of which are given at D, Fig. 71, is constructed with horizontal spaces at the centre and each end. In the middle it is secured to the column by four screws, and to the braces B in the same manner, the holes for which are marked in all the views.

The square opening in the middle serves as a guide and support to the lifting-frame, which must be accurately fitted, so as to prevent any lateral play.

The horizontal spaces at the extremity of the cap-plate support short pillars terminated by cones, upon which the beam rests; these pillars are secured to the cap-plate by screws passing through it from the under side, the holes through which they pass being large enough to admit of the adjustment of the beam to its proper place, previous to their being permanently fastened down.

The details of these pillars are given at *l*, Fig. 72, the cones being constructed of cast steel, hardened and polished.

The same space also supports the V's, or guide supports of the hangers, different explanatory views of which are given in Fig. 72, the V's being marked *m*, and the hangers *n*. All these parts have been devised with reference to the simplest and most economical construction consistent with the requisite accuracy, and for affording the greatest facility in the final adjustment of the balance.

The most important part of the balance is the beam *o*; and Fig. 72 exhibits side and top views. The projections marked *q*, are the supports of the beam when at rest; the conical cavities, indicated by dotted lines, being made to fit the cones marked *l*.

This form of beam affords facility in construction, being composed of straight surfaces, without ribs or curves; is well adapted to maintain its form when loaded; affords the least surface for accumulation of dust, and is readily wiped when it may be necessary. The means of adjustment for the length of arm is exhibited at *r*, Fig. 72.

It will be seen, that the needle of the balance which is the subject of description, is pointed downwards; and there are good reasons for this disposition. In the first place it is directly before the eye of the operator, and, therefore, more convenient in use, than it is when elevated above; again, it may be made longer than the arms of the beam, and will, consequently, describe a larger arc, and thus give more distinct indications, whilst the whole arrangement need occupy no more space than is requisite for the other parts; and, finally, the needle is protected from external injury by the lifting-frame and column, in the centre of which it is placed.

The parts which remain to be described have been usually considered of minor importance, but experience has shown that

this estimate is scarcely a just one, inasmuch as they afford facilities for accuracy and rapidity, that leave no doubt of their value, and place them in a most important position in practice. The parts now alluded to, constitute the system by which the operator is enabled to find the equilibrium of which he is in search. It consists of the pedestals, as they have been termed, marked *s*, Figs. 70 and 71, and the parts connected with them, marked *t*, *u*, *v*, and *w*, in Fig. 71; a light shaft, made of tubular iron, *t*, supported by pivots *u*, which pivots are screwed through a piece cast on the under side of the table, marked V; upon the ends of this shaft there are levers W, upon the ends of which levers, when in place, the pedestals rest.

The remaining part of this system is a double armed lever, placed in the middle of the shaft *t* (represented in the engraving detached), and marked *x;* it is connected by a pin, with the trigger, *z*, represented in its place in Fig. 71, with the same letter. Upon the other end of the lever *x*, there is a weight *y*, capable of adjustment by a screw upon which it traverses, so that it may be made to approach, or recede from the shaft *t*.

The action of this system is easily understood; its whole object is to depress the platforms by sufficient force, applied by the finger, to the trigger, the counter-weight returning them to their original position, after its removal.

It will be seen, by reference to Fig. 70, that the under sides of the stirrups have a space, represented by dotted lines, in which the platforms are placed, which allows the stirrups to oscillate within its limits, but beyond which they cannot move. This construction is intended to guard the hangers from displacement, and to prevent injury by too much movement of the stirrups, an accident very likely to occur, when the pans or weights are hastily removed, especially in the use of heavy weights or large masses.

The cavity, whose object was described in the last paragraph, forming the under side of the base of the stirrups, is turned as truly as possible in the form of a portion of a sphere, whose radius is its distance from the bearing of the knife-edge. The platforms are adjusted by means of the counter-weight, so as to press lightly up against the stirrups, and to follow them when raised.

It is found convenient in practice to turn the handle of the balance but a small portion of its movement, if the weights are not equal on opposite sides, a circumstance to be expected when searching for a weight. The heavy side will remain down, and the needle will indicate whether addition of weight or its removal is requisite. These trials are continued until the platforms follow up the whole lift, the needle remaining opposite the middle line of its scale, until the handle is stopped by its limit of motion, where it remains. The finger, then, by pushing down the trigger, will depress the platforms, when smaller weights are employed, until the needle indicates equilibrium.

In this balance there is little or no embarrassment from oscillation, because the stirrups immediately accommodate themselves to the position of the weights, the light pressure permitting them to take any position required by the load; nevertheless, having sufficient power, from their pressure, to prevent any swinging. If from any cause the stirrups should be in motion, three consecutive depressions of the platforms will bring them to a state of rest with absolute certainty, and with a loss of time so short as to be entirely immaterial.

The stirrups are connected with the hangers, by a rod, which is double-jointed, as near to the hangers as possible, so as to allow perfect freedom of motion; at the same time, so well fitted as to allow no change of position in the parts. On the lower ends of these rods there are screws and nuts, to regulate the height of the stirrups, together with a jam-nut, to prevent any change after the adjustment has been satisfactorily made.

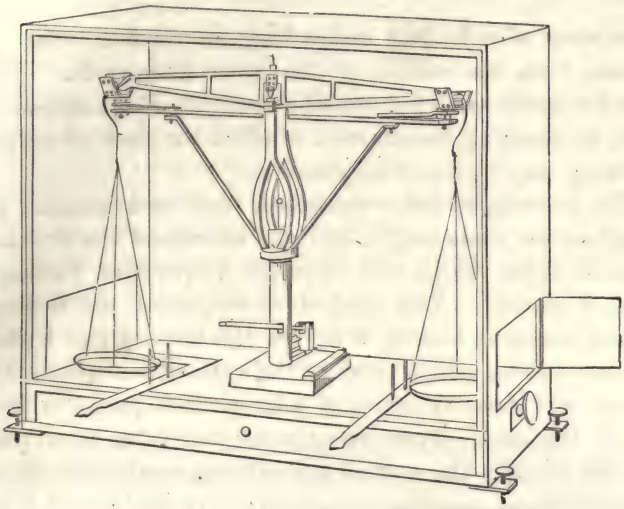
The bases of the stirrups are designedly made small, requiring the use of a dish on the one side, and a platform for weights on the other. This dish and platform being made of equal weight, renders the use of a counter-weight unnecessary; and as the balance cannot be used without both, the liability to mistakes from this cause is entirely avoided.

The principle of the Mint balance has been adopted in the construction of one of our finest analytical balances, which was made for us by John Jones, Baltimore.

Kater's and Robinson's balance. This, Fig. 73, though more complicated than the preceding, is an excellent balance for estimating minute quantities with precision; and, indeed, for all the

weighing operations of delicate research. When carefully preserved, it retains its sensibility for many years.

Fig. 73.



We are indebted for our description to *Lardner's Elements of Mechanics.*

"The beam of this balance is only ten inches long. It is a frame of bell-metal in the form of a rhombus. The fulcrum is an equilateral triangular prism of steel, one inch in length; but the edge on which the beam vibrates is formed to an angle of 120°, in order to prevent any injury from the weight with which it may be loaded. The chief peculiarity in this balance consists in the knife-edge, which forms the fulcrum, bearing upon an agate plane throughout its whole length; whereas in the other balances the whole weight is supported by portions only of the knife-edge, amounting together to one-tenth of an inch. The supports for the scales are knife-edges, each six-tenths of an inch long. These are each furnished with two pressing-screws, by means of which they may be made parallel to the central knife-edge.

"Each end of the beam is sprung obliquely upwards and towards the middle, so as to form a spring through which a

pushing-screw passes, which serves to vary the distance of the point of suspension from the fulcrum, and, at the same time, by its oblique action, to raise or depress it, so as to furnish a means of bringing the points of suspension and the fulcrum into a right line.

"A piece of wire, four inches long, on which a screw is cut, proceeds from the middle of the beam downwards. This is pointed to serve as an index, and a small brass ball moves on the screw, by changing the situation of which the place of the centre of gravity may be varied at pleasure.

"The fulcrum, as before remarked, rests upon an agate plane throughout its whole length, and the scale-pans are attached to planes of agate, which rest upon the knife-edges, forming the points of support. This method of supporting the scale-pans, we have reason to believe, is due to Mr. Cavendish. Upon the lower half of the pillar, to which the agate plane is fixed, a tube slides up and down by means of a lever which passes to the outside of the case. From the top of this tube, arms proceed obliquely towards the ends of the balance, serving to support a horizontal piece, carrying at each extremity two sets of *Y's*, one a little above the other. The upper *Y's* are destined to receive the agate planes to which the scale-pans are attached, and thus to relieve the knife-edges from their pressure; the lower to receive the knife-edges themselves, which form the points of suspension of the pans, consequently these latter *Y's*, when in action, sustain the whole beam.

"When the lever is freed from a notch in which it is lodged, a spring is allowed to act upon the tube we have mentioned, and to elevate it. The upper *Y's* first meet the agate planes carrying the scale-pans, and free them from the knife-edges. The lower *Y's* then come into action, and raise the whole beam, elevating the central knife-edge above the agate plane. This is the usual state of the balance when not in use: when it is to be brought into action, the reverse of what we have described takes place. On pressing down the lever, the central knife-edge first meets the agate plane, and afterwards the two agate planes, carrying the scale-pans, are deposited upon their supporting knife-edges.

"A balance of this construction was employed by Captain

Kater in adjusting the national standard pound. With a pound troy in each scale, the addition of one-hundredth of a grain caused the index to vary one division, equal to one-tenth of an inch; and Mr. Robinson adjusts these balances so that with one thousand grains in each scale, the index varies perceptibly on the addition of one-thousandth of a grain, or of one-millionth part of the weight to be determined."

Duffy has added a very simple but useful improvement. It consists of an elastic spring, A A, Fig. 74, serving as a support for the dishes when the balance is at rest; and at the same time so arranged, that by the depression of the thumb-lever suitably attached, the dishes are thrown off their supports, and the beam put into action simultaneously.

Fig. 74.

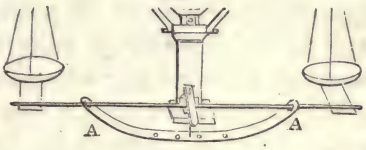
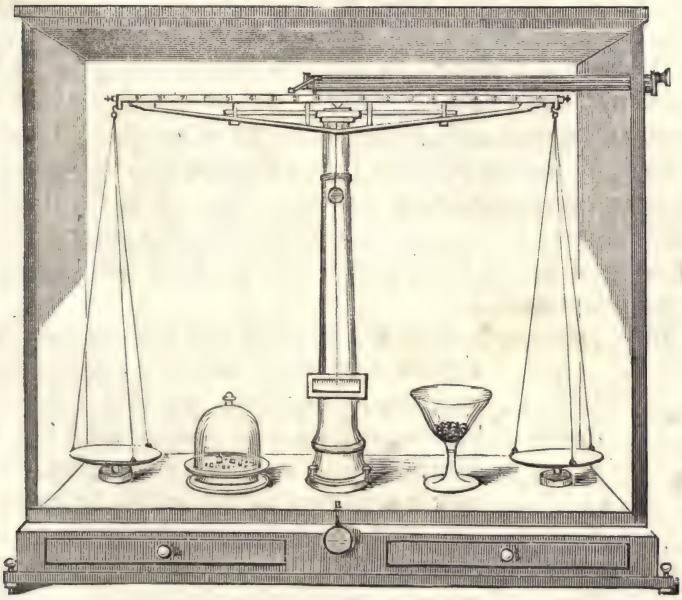


Fig. 75.



Berlin Balance.—This pattern of balance combines, in an eminent degree, all the requirements of a convenient and exact weighing apparatus at a moderate cost. It is, therefore, deserv-

edly popular with chemists for the analytical and delicate weighings of the laboratory. Fig. 75 presents the instrument in its most improved form.

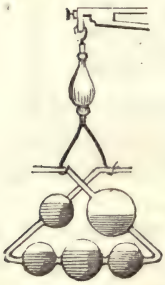
The support and beam are, as usual, of brass; the pans of platinized copper, and the suspension wires of the same material, or pure platinum. The beam is constructed with knife-edges at the ends, and upon which the pans are suspended by agate planes. The centre knife-edge also moves upon an agate plane; and to bring all the knife-edges into the same straight line as well as to equalize the lengths of the arms of the beam, the latter is fitted with a suitable means of adjustment. A screw-knob above the centre of the beam serves to adjust the centre of gravity.

The balances are made either with or without supports to the pans, as may be preferred by the operator; but, in either case, there is a mechanical system for steadying them. It connects with the same axis which moves the beam, so that one movement of the handles first releases the pans and then the beam. When supports are used, they must be faced with ivory to prevent the pans losing any weight by abrasion of their under surfaces.

The beam is graduated on each arm into ten divisions, for the use of a sliding-weight or "*rider;*" and an apparatus above the beam, at the right side, serves, by means of an external handle or knob, for moving the rider from division to division, as may be necessary, without opening the case. The use of the rider, as will be learned in the chapter on WEIGHING, does away with the necessity of having weights lower than the hundredth of a grain or a centigramme.

These balances are generally provided with the supplementary apparatus for taking specific gravities and for weighing tubes, bulbs, &c. (Fig. 76). The lantern, or glass case, is constructed with adjusting screws to maintain a perfect level; and the drawers at the bottom being fitted with plush-covered receptacles for the several parts of the apparatus, it becomes a safe means of transporting the instrument without the trouble of special packing. The sliding part and back, and the hinged doors at the end, afford every facility for weighing long

Fig. 76.



tubes and similar apparatus; and in the finer balances, the bottom is of glass-plate, which contributes materially to the good order of the balance, as it may be readily kept clean. These balances cost $30, $60, $90, and $125, according to finish, and inclusive of weights. Those at the lowest prices will carry four hundred grains, and turn with one-fiftieth of a grain. Those of greatest delicacy will turn with one-thousandth of a grain when loaded with fifteen hundred grains.

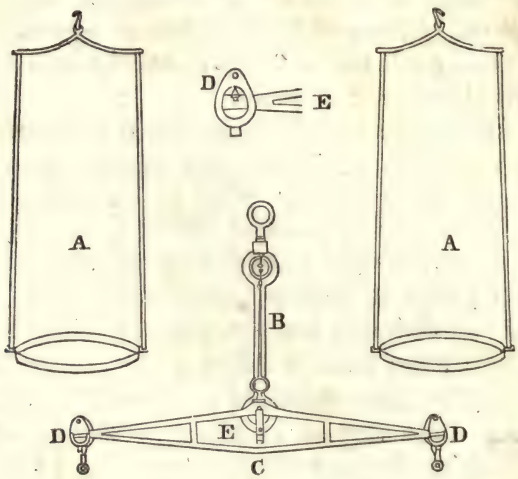
Assay Balance.—This instrument should be constructed with great skill and accuracy; for it is used only for the very precise weighing of minute quantities. When the luxury can be afforded, the laboratory should be provided with one; but otherwise the analytical balance may be made to serve its purposes. To this end, it must always be kept in perfect adjustment. For blowpipe operations, Plattner's Assay Balance will be found very satisfactory. If skilfully made, it will turn with one-fifth of a milligramme; but the pans should be suspended by platinum wire instead of a silken cord as at present. The top of the box forms the base for the pans, which are raised by a lever. These balances, compactly arranged in portable boxes, cost, with weights, from $26 to $32.

Tralle's Balance.—This is an appropriate apparatus for weighing heavy or bulky articles, of which the required quantities are large, for example, gold ores, vegetable matters, &c., intended for analysis and investigation; as in such instances, the dusty emanations would render the use of the finer mint balance injudicious. They are made of sufficient delicacy to turn with one or two grains when loaded with five pounds, and at a cost of only $20 to $25.

The annexed drawing represents the instrument, which consists of two brass dishes A A, suspended by loops D D, resting upon the steel knife-edges at the extremities of the beam C. The beam is supported by the knife-edge in its centre as at E, and the whole balance is suspended to an upright, crooked at its top, by the hanger B. Annexed to the centre of the beam is a long vertical needle, which, following the vibrations of the beam, serves to indicate the least oscillation, which is rendered more perceptible by an ivory segment situated behind its point, and divided into degrees. This balance is placed in the room D, Pl.

2, upon the table adjoining that upon which is the finer balance. The support to which it is suspended may be either of wood or metal. To prevent damage to the knife-edges, the dishes, when

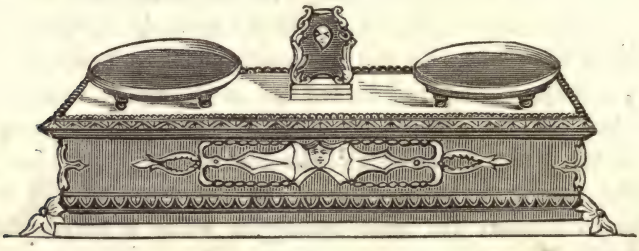
Fig. 76 a.



the scales are not in use, should be unhung, and the whole balance kept covered with a linen cover, distended over a wire framework, which may be suspended by a cord upon a pulley, and counterpoised so as to admit of being readily raised or lowered. It would add to the durability of the balance to gild the knife-edges.

Platform Balance.—This is for the general purposes of the store-room. The best form is that known as "Beranger's Pen-

Fig. 77.



dulum Scale," Fig. 77, as it combines the advantages of precision, strength, and durability.

Preservation of the Balances.—Each of the finer balances should have a separate table, and these tables a permanent position in a close, well-lighted room, expressly appropriated for the purpose. The top of the table must be of hard wood and perfectly horizontal; and to secure the table itself against the slightest jarring motion, it may be tightly fastened to the floor by iron clamps and screws fitted to its legs. Great care is requisite to have it plumb. Of the two drawers which it should contain, one is for the spatulas, spoons, crucible tongs, papers, watch-glasses, and other implements used in weighing; the other may be fitted deskwise, and furnished with slips of paper, or a porcelain slate and pencil, to afford convenience in recording the weights. A polished cast iron slab, about six inches square, upon which to set the heated crucibles and promote their cooling by conducting off the excess of heat previous to weighing, may be considered a necessary accompaniment of the table. In order to preserve its brightness, it should be encased in a woollen bag and kept within the drawer when not in use; or it may be enclosed in a frame with a sliding cover, and fastened to the top of the table near to one of its corners. The cover which protects its surface from oxidation can readily be drawn out whenever it is required to use the slab.

It is not sufficient for the preservation of the delicacy of the balances, that the room in which they are kept should be dry and tight. Vapors, aqueous and corrosive, will in divers ways find entrance into the apartment, and so, therefore, besides the precaution of lacquering the brass and gilding the steel parts of the balance, the instrument should be enclosed in a sufficiently capacious mahogany or walnut case, with sash-doors in the front and back, and sash-windows at either side. The doors should be always kept closed and fastened by their buttons when the balance is not in use, else the entrance of dust and moisture will impair its accuracy. An additional and very effectual precaution against oxidation by moisture, is to keep constantly within the case a glass containing some absorbent matter, as fused chloride of calcium or carbonate of potassa. By an occasional renewal of the absorbent matter, the atmosphere within the case can be kept very dry. The multiplication of doorways is to afford facility for the passage and weighing of long tubes, which have to

be placed across the pan. The divisions in the drawer at the bottom of the case must be lined with velvet, and so arranged as to receive the different parts of the balance, and allow its transportation without the least risk of damage.

In order to preserve the edges of the knives, the beam should always be thrown out of action when the balance is not in use, otherwise their constant contact with the planes, and the pressure of the balances, as well as the sudden addition of a heavy weight, will injure their delicacy.

The three or four feet upon which the case rests have screws passing through them. These serve to give the balance a perfectly horizontal position, even upon an uneven surface—the level being obtained by raising or depressing either of the screws, as the case requires, and as will be indicated by the two spirit-levels, which should be fitted to the pedestal of each balance.

The position of the balance should be with due regard to light, but while placed near the window, to afford facility in perceiving the slightest oscillations of the needle, it should be free from draughts of air, and also from the action of the solar rays, which, by producing unequal expansion of the different parts, would occasion inexact results in weighing.

The balances should be cleansed and adjusted whenever they have become inaccurate, for it is almost impossible for even the best balance to retain its sensitiveness indefinitely. This work should rather be confided to a manufacturer of balances, as it requires both skill and experience. Slight discrepancies in the weight of the two dishes can be temporarily compensated for by adding to that dish which is deficient, sufficient weight to restore its equilibrium.

CHAPTER VI.

THE WEIGHTS.

There are three sets of weights requisite, of which one for the platform balance of the store-room should be avoirdupois, and range from eight or more pounds downward to a quarter of an ounce. These weights are for the rougher operations of

weighing, and may be of brass or of cast iron coated with black japan to protect them against oxidation.

For the larger balances, a finer and exact set is necessary. They should be made of brass, in the form of short cylinders, *f*, Fig. 80, with knobs at the top, and range from 25,000 to 0·1 grains, decreasing by fives in the series to 500, as follows: 25,000, 20,000, 15,000, 10,000, 5,000, 1,000, 500; and from that point as follows: 400, 300, 200, 100, 50, 30, 20, 10, 5, 4, 3, 2, 1, 0·1.

The weights for the analytical or assay balances must be of the finest and most precise workmanship.

If they are grain weights, the series should range from 5,000 grains to $\frac{1}{1000}$th of a grain, as follows: 5,000, 3,000, 2,000, 1,000, 500, 300, 200, 100, 50, 30, 20, 10, 5, 3, 2, 1, ·1, ·2, ·3, ·5, ·05, ·03, ·02, ·01, ·005, ·003, ·002. The gramme weights range from one centigramme to one milligramme. The divisions of the gramme (the standard unit of the French weights) are the *decigramme* = $\frac{1}{10}$th gramme; the *centigramme* = $\frac{1}{100}$th gramme; the *milligramme* = $\frac{1}{1000}$th gramme. Its multiples are the *decagramme* = 10; the *hectogramme* = 100; the *kilogramme* = 1000; and the *myriagramme* = 10,000 grammes. The table below shows the relative value and proportions of the French decimal and troy and avoirdupois weights:

Metrical or Decimal Weights.

Names.	Equiv. in grammes.	Equiv. in Troy grains.	Equiv. in avoirdupois weight. *lbs.*	*oz.*	*grs.*
Milligramme,	·001	·0154			
Centigramme,	·01	·1543			
Decigramme,	·1	1·5434			
Gramme,	1·	15·434			
Decagramme,	10·	154·3402		0¼	45·
Hectogramme,	100·	1543·4023		3½	12·152
Kilogramme, or Kilo,	1000·	15434·0234	2	3¼	12·173
Myriagramme,	10000·	154340·2344	22	0¾	12·

All of the weights for the fine balance must be adjusted with the nicest accuracy, and before being used should be compared with others of attested correctness. Of the French weights those from the milligramme to the gramme should be of platinum; and so, also, of the grain weights, those from the ten-grain weight downwards should be of the same metal. Palladium being of

but half the specific gravity of platinum, and similar to it in other respects, is sometimes used for the fractional grain weights, because of the greater relative surface which it presents. They are frequently made of silver, and gilded. Aluminium being very light might also be used for the purpose. The remaining larger weights, to save expense, may be of brass, and, to preserve them from oxidation, should either be covered with a thin coat of lacquer, or, better, galvanized with gold or platinum.

Each set should contain duplicates of the 10, 2, and 1 grain weights; triplicates of the ·2, ·1, ·02, ·01, and quadruplicates of the ·001 grain weights; for in many instances, especially in taking specific gravities, these additional weights are indispensable. Berlin balances are provided with "*riders*," which do away with the necessity of having weights less than a centigramme, or hundredth of a grain.

In order to preserve the weights free from dust and oxidation, they must be encased in a close box with hinged cover and fastenings. The interior of the box should be divided into compartments, lined with velvet, to prevent abrasion of the surfaces of the weights, each of which must have a separate division. The edges of every compartment should be marked in ink with the value of the weight it contains; and the weights themselves must have their denominations stamped upon them. The series must be so accurately adjusted, that the difference between any one of the large weights and the combined number of smaller ones, equal to it, shall not be perceptible in a balance turning with one-tenth of a milligramme.

To test their accuracy, take any two of them of the same denomination, convey them, with the fork or forceps, to the balance, and place one in each dish. If the beam upon being put in action is in perfect equilibrium, the weights are uniform, and can serve as standards. Then, for further verification, place both together in one dish, and in the opposite pan add enough of smaller weights to equal that of the two combined. If the beam still retains its equilibrium, when put in action, the weights may be considered correct.

As frequent handling of the weights with the fingers would tarnish them, and otherwise injure their value, a small fork and a pair of forceps are necessary accompaniments to each set of

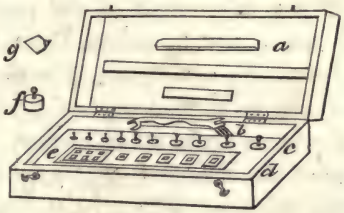
weights. The fork, represented by Fig. 78, made of either ivory, horn, or wood, and being intended for raising the brass weights, has its notches at either end of different size, so as equally to accommodate the knobs of both the larger and smaller weights. A small pair of elastic forceps, Fig. 79, of brass or plated, or polished steel, with ivory points, serve for the smaller platinum weights, which, for convenience of handling, should be turned up at one corner, as at *g*, Fig. 80.

Fig. 78. Fig. 79.

The box should be closed after each weighing, and, to preserve it from the corrosive vapors that may be floating about, should be kept in the drawer of the balance-table.

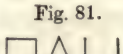
Fig. 80, represents a box of weights and all the necessary appurtenances. The ribs, *a a a*, fitted to the interior of the top, by pressing against them when the box is closed, keep the weights in their places. The fork and forceps are shown in place at *b b*. The channel *d*, kept always covered with a thick glass plate, contains the platinum weights, an extra quantity of the smaller of which are kept in the cavity *e*. When the weights are in constant use for the day, they may be, during that period, kept on a small stand under a glass cover near the balance-pan, as shown in Fig. 75. This will save the inconvenience and delay of repeated transfers to and from the box and balance.

Fig. 80.



Small weights may be made, by first determining the weight of a given length of wire of uniform thickness throughout, and then dividing it into perfectly equal parts;—the number of the divisions or angles indicates the fraction of the original weight which they represent as a whole; for instance, if the wire weighed ten grains, and is divided into 10 or 20 portions, each fraction will represent a grain or half grain, accordingly. By using wire of greater thickness, weights of augmented value can, in like manner, be made and adjusted. This form, as shown (Fig. 81), is that

Fig. 81.



in which all weights below ten grains are now, generally, made.

Shot, of which there should be a box of the several sizes kept in the balance table-drawer, are convenient counterpoises for tubes, capsules, crucibles, watch-glasses, and other receptacles for substances to be weighed.

CHAPTER VII.

WEIGHING.

THERE are certain preliminaries to be observed in all delicate weighing operations, of which the most important is to ascertain whether the balance is in order, as regards equilibrium and freedom of oscillation. To do this, each dish should be loaded nearly to the full extent of the power of the balance. If, when the beam is put in action, there is no perceptible variation in the dishes, the equilibrium is perfect. For further verification, there should be an exchange of loads, from one dish to the other, and the beam again set in motion. The recovery of the equilibrium, after the cessation of the vibrations, indicates the correctness of the balance. The need of more than a milligramme for the analytic balance, or of $\frac{1}{10}$th of a milligramme in the more delicate balance, to restore a deficiency in either dish, should condemn the instruments for quantitative examinations, unless previously adjusted. This is done by the addition of bits of tin-foil to that dish which is lightest. When, however, the balance is carefully used, and by but one operator, it will be only necessary to reassure himself of its equilibrium in those weighings where absolute accuracy is all-important. Be careful, however, in adjusting, as well as in weighing, that the weights in the pan do not overload the balance and make it *set*, an effect the more prompt, in proportion to the greater accuracy and sensibility of the balance. The setting, which makes one scale appear heavier than the other, is a permanent depression of the lowest pan by the slightest impulse to the exactly horizontal beam of a surcharged balance. Hence the necessity of loading the balance within the limit of its maximum power.

In all weighing operations, the counterpoising of substances is more speedily attained, and with less injury to the balance, by systematically following a weight, which is removed from the pan as too heavy, by the next in succession, until equilibrium is obtained. Thus, in balancing a watch-glass, if the 20 grain weight drags the beam, replace it by the 15; if this is still too much, use the 10 weight; and if this is too little, make up the deficiency with the smaller weights, by adding them consecutively, and decreasing gradually their denomination as the counterpoise is approached.

To preserve the accuracy of the balance, it should be put out of action upon every addition, removal, or substitution of weights. As a precaution against error, the weights must always be removed from the pan and spread upon white paper to be counted; and to verify the aggregate, in putting them away, their denominations should also be compared with their value, as marked upon the vacancies which they occupy in the box in which they are kept. The slips of paper and porcelain slate, in the table-drawer, serve to make notes of their amount, which should be done before placing them in the box.

A provision against inaccuracy, from very slight inequality of the arms of the beam or imperfect equilibrium from other causes, is the invariable use of the same pan for the reception of the substance to be weighed. By this practice, notwithstanding the difference in the weights of the two dishes, the ratio being kept uniform, the quantities will be proportionably augmented or decreased, so that the products of analyses can be as accurately estimated as in a perfect balance. An alternate use of the pans for the weights and the substance to be weighed, will, on the contrary, lead to results too high or low, as the case may be. We, however, obtain, in this way, only the *relative* weight of the substance, and not its *absolute* weight, which requires a perfect balance.

Borda proposes to avoid the errors of inaccurate balances, by first taking the tare of the substance with that or any other counterpoise, and afterwards substituting, in its stead, weights sufficient to restore the equilibrium, which was disturbed by its withdrawal from the dish. The sum of these added weights represent exactly that of the substance being weighed. This mode

is termed *double weighing*, and affords very nice results even in balances with disproportioned beams.

In weighing with the Berlin, or any balance having the arms of its beam graduated into decimal divisions, all weights less than the tenth of a grain, or the one-hundredth of a gramme, may be dispensed with, as the *riders*, heretofore described at p. 118, are much more convenient, and afford very prompt and accurate results.

They are looped forks of fine gilt wire, Fig. 82, weighing exactly ·1 of a grain for grain weights, and ·01 of a gramme for gramme weights. As the value of its weight upon the beam depends upon its distance from the point of suspension of the latter, it must be placed thereon, and moved along from division to division until the exact point is attained, by means of the arm and knob mentioned at p. 112. For example, the weight of the rider being one-tenth of a grain, it expresses at division one, one-hundredth placed in the pan; at division two, two-hundredths, and so on. To obtain intermediate values, the decimal divisions of the arm must be further subdivided. In the use of gramme weights, the rider being exactly ·01 of a gramme, any weight, from a centigramme downwards, may be determined in the manner just mentioned.

Fig. 82.

Weighing of Solids.—The balance being in perfect order and repose, the next step is to counterpoise the vessel in which the substance, which should in no instance be placed upon the naked dish, is to be weighed. Circular disks of highly glazed paper are sometimes used as recipients, but being attractive of moisture, are preferably replaced by a watch-glass, or crucible of platinum or of porcelain. The recipient being placed upon the pan, appropriated exclusively for the purpose, is then accurately counterbalanced by shot or fragments of metal. In analyses, the counterpoise must be preserved for future references. They may be either wrapped in paper or enclosed in paper pill-boxes, but in either case must be labelled. In delicate analyses, to avoid error, the tare of the vessel should be estimated in weights, and their amount immediately noted down, to be afterwards subtracted from the combined weight of it, and the substance

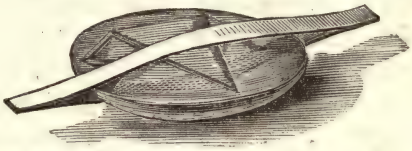
weighed. The tare of the drying tubes, or of Liebig's and other apparatus used in organic analysis requiring to be weighed, to prevent mistakes, should be labelled upon the implements themselves with which it corresponds. This done, the substance is introduced into the recipient, if in lumps, by means of a pair of forceps with platinum points; if in powder, with an ivory, horn, or platinum spoon or spatula, accordingly as it may be inert or corrosive. The blade of the spatula should never be of steel, as it is so liable to oxidation. A slip of very thick sheet platinum, one inch in width and two inches long, fastened in a wooden or metallic handle, is generally used. Its usefulness for this purpose may be increased by alloying it with a very minute portion of silver, which increases its elasticity in an eminent degree. The weights are added to the opposite dish, and always after throwing the beam out of action, through the side-door of the case, which must be immediately closed after each addition. If, when the balance is lifted from its supports, by means of the thumb-screw or lever, the index needle turns rapidly towards the dish opposite to the weights, the balance must be put in repose, another weight added, and the motion of the needle again examined. This operation should be repeated upon the addition of each weight, however small. As the pans approach equilibrium, the vibrations of the needle decrease in rapidity, and a little experience and observation will enable the operator to determine the right point after one or two trials. When any given quantity of a substance is to be weighed, the requisite weight should be placed in the dish first, and the substance, if in powder, deposited in the other dish with a spoon or spatula, until an accurate counterpoise is obtained; taking care, however, to bring the balance at rest upon each addition of material, which may be made to fall in very minute quantities from the spatula by gently tapping against its handle with the finger.

Those substances which are hygroscopic, should be weighed in a covered vessel; for instance, between two watch-glasses, Fig. 83, or in a small tube with a ground stopper, which may be held in an upright position by a loop of platinum wire slipped over the suspending wire of the pan, or by a cork and wire stand, as shown by Fig. 84.

The more delicate balances have for this purpose, for that of

organic analysis and of weighing substances in water, a supplementary pan, with a hook beneath, for convenience of suspension.

Fig. 83.



This pan, which descends from the beam only one-half the distance of the other, is shown in the chapter upon SPECIFIC GRAVITY.

After the weighing is completed, the weights, as before directed, are withdrawn with forceps, placed upon a piece of white paper, and their several amounts added together;—the total gives the weight of the substance in the opposite dish.

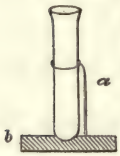
Covered vessels are also requisite for those corrosive substances, the exhalations from which would be injurious to the balance, and impair its accuracy.

Substances should never be weighed whilst hot, even in closed vessels, otherwise the ascending current of air thus produced draws after it a current of cold air, and not only promotes an unequal expansion of one arm of the beam, but also an upward motion to the pan, which will lead to error. A crucible, therefore, which has been over the lamp for the ignition of its contents, should be first cooled by standing upon the iron slab accompanying the balance-table, otherwise its *hot* weight, not corresponding with its *cold* weight, would, in estimating the result, lead to an error in the real weight.

Weighing of Liquids.—The nature of liquids, especially their temperature and volatility, have an important influence upon the precision of the results.

Non-volatile liquids may be weighed in a counterpoised capsule, watch-glass, flask, or tube. Those vessels which have spherical bottoms are supported in the pans upon cork rings, which are readily made by hollowing out a cork and bevelling its upper edges interiorly. If the recipient is tall, it requires a stand to maintain it in an upright position. This stand, shown by Fig. 84, is nothing more than a disk of cork *b*, with the wire-catch *a*, fastened to it. An excellent substitute is a broad cork, with a hole in its centre, corresponding with the

Fig. 84.



size of the tube, and bored smoothly and nearly through the cork with the cork-borer hereafter to be described. The use of the wire-loop, before mentioned, is less safe and convenient for suspending these vessels.

The liquids are conveyed to the recipients in dropping-tubes or pipettes. This mode allows their gradual addition, and in small quantities.

Any excess of the liquid, preventing a perfect adjustment, may be removed from the recipient with an empty pipette in the same manner as it was introduced. With a little precaution in the management of the pipette, the flow may be made so gradual that it can be arrested as soon as the vessel has received the required quantity. The insertion of slips of bibulous paper serves to withdraw any slight excess, unless the liquid is corrosive and acts upon paper, in which case, a glass rod must be substituted. The insertion of this rod into the liquid, and its subsequent withdrawal, causes a loss thereto of the small adherent quantity, and thus we have a means of accurately weighing any required quantity of liquid.

The stock of pipettes should consist of several sizes. After being used, they should be carefully laid across a porcelain plate, there to remain until the completion of the weighing, when they must be well rinsed out previous to being returned to their places in the drawers.

All volatile substances must be weighed in the small, closely stoppered flasks, tubes, sealed glass bulbs, or other vessels, previously counterpoised. To insure accurate results, care must be taken that the temperature does not favor volatilization. Fuming liquids should, if possible, be measured.

Very deliquescent substances, such as are not checked in their liquefying tendency by the greatest practicable dryness of the balance-case, and are not alterable by water, should be weighed in solution. First, pour into the counterpoised recipient a sufficiency of water, and note its weight. The increase of weight given to this water by the addition of the deliquescent body, is the actual weight of the latter, and the solution can be used in the analysis instead of the solid. In some instances, according to the nature of the substance, alcohol, or other more appropriate liquid, may be substituted for water.

Weighing of Gases.—In weighing gases, it is necessary, in order to obtain nice results, to guard against the least variations of temperature, pressure, and humidity of the atmosphere. Gases are readily estimated by means of a very sensitive balance, though the old plan, by *measurement* of volume in graduated vessels, is accurate and easily executed.

Gases are weighed in counterpoised balloons, which must be thoroughly cleaned and dried, and wiped exteriorly and interiorly, so as to remove every particle of grease, dirt, or dust. The balloon is then to be connected by a coupling-cock fitted to its neck, with an air-pump Fig. 47, or syringe, Fig. 86, and exhausted of its air. To insure the expulsion of all remnants of gas from a former weighing, the balloon should be subjected to repeated alternate exhaustions and airings. The exhausted balloon is then to be attached to a graduated bell-glass, also fitted with a coupling-cock, as shown by Fig. 85. This bell-glass is the reservoir of the gas which is received or collected over (*see* PNEUMATIC TROUGH) water or mercury. Communication between the balloon and bell-glass, being made by opening their connecting-cocks, the gas rushes from the latter into the former by force of atmospheric pressure upon the mercury. When the balloon is filled, the flow is to be stopped by closing the cocks. A delay of several minutes is necessary (*see* MEASUREMENT AND TRANSFER OF GASES) to allow the temperature within the bulb to become that of the external air, that the level within and without the bell-glass may be equalized, and the quantity of gas noted. The balloon must then be detached, and again weighed with care and accuracy. The difference between its present and original weight, is that of the volume of gas which it contains.

Fig. 85.

Fig. 86.

In the weighing of gases, it is indispensable to note the temperature and barometric pressure, and to observe all other conditions and precautions requisite in the MEASUREMENT OF GASES.

Those gases which are without action upon mercury, ought to be collected over that metal, for most gases, by contact with water, absorb more or less of its vapor, according to the tempera-

ture; and, therefore, to insure correct results, it is generally preferable to purify the gas of moisture *previous* to weighing it. This is done by passing it through a tube (*see* DESICCATION OF GASES) containing fused chloride of calcium, or some other absorbent substance.

It must be remembered, however, in the desiccation of gases, by transit through tubes containing absorbent matter, that the quantity of *dry* gas, entering into the globe, is less than that received from the bell-glass, the volume of vapor abstracted in its passage. To determine the amount of this loss, "observe the temperature of the moist gas, and correct its volume by the pressure of thirty inches of mercury. Then, by the table below, ascertain the proportion of vapor which was present in the volume which left the jar, and subtract it from the corrected volume;—the remainder will be the volume of dry gas which has entered the globe."

The table, taken from Faraday, "exhibits the proportion by volume of aqueous vapor existing in any gas standing over or in contact with water, at the corresponding temperatures, and at mean barometric pressure of thirty inches."

40° — ·00933	51° — ·01380	61° — ·01923	71° — ·02653
41 — ·00973	52 — ·01426	62 — ·01980	72 — ·02740
42 — ·01013	53 — ·01480	63 — ·02000	73 — ·02830
43 — ·01053	54 — ·01533	64 — ·02120	74 — ·02923
44 — ·01093	55 — ·01586	65 — ·02190	75 — ·03020
45 — ·01133	56 — ·01640	66 — ·02260	76 — ·03120
46 — ·01173	57 — ·01693	67 — ·02330	77 — ·03220
47 — ·01213	58 — ·01753	68 — ·02406	78 — ·03323
48 — ·01253	59 — ·01810	69 — ·02483	79 — ·03423
49 — ·01293	60 — ·01866	70 — ·02566	80 — ·03533
50 — ·01333			

This table is also useful for determining that part of the volume and weight of a moist gas, due to aqueous vapor after it has been weighed without previous desiccation, for as it "includes any temperature at which gases are likely to be weighed, the proportions in bulk of vapor present, and consequently of the dry gas, may easily be ascertained. For this purpose the observed temperature of the gas should be looked for, and opposite to it will be found the proportion in bulk of aqueous vapor at a pressure of 30 inches. The volume to which this amounts should be ascertained and corrected to mean temperature. Then the

whole volume is to be corrected to mean temperature and pressure, and the corrected volume of vapor subtracted from it. This will leave the corrected volume of dry gas. It has been ascertained, in a manner approaching to perfect accuracy, that a cubic inch of permanent aqueous vapor corrected to the temperature of 60°, and a mean pressure of 30 inches, weighs 0·1929 grains. The weight, therefore, of the known volume of aqueous vapor is now easily ascertained, and this being subtracted from the weight of the moist gas, will give the weight of the dry gas, the volume of which is also known.

"As an illustration, suppose a gas standing over water had been thus weighed, and that 220 cubic inches at the temperature of 50° Fahr., and barometric pressure of 29·4 inches had entered into the globe and caused an increase in weight of 101·69 grains. By reference to the table it will be found that at the temperature of 50°, the proportion of aqueous vapor in gas standing over water is ·01333, which in the 220 cubic inches will amount to 2·933 cubic inches, which, corrected to the temperature of 60°, becomes 2·942 cubic inches. The whole volume corrected to mean temperature and pressure will be found to equal 219·929 cubic inches, from which, if the 2·942 cubic inches of aqueous vapor present be subtracted, it will leave 216·987 cubic inches as the volume of *dry* gas at mean temperature and pressure: 2·942 cubic inches of aqueous vapor weigh ·5675 grains, for $2{\cdot}942 \times 0{\cdot}1929 = 0{\cdot}5675$; this subtracted from 101·69, the whole weight, leaves 101·1225 grains, which is the weight of the 216·987 cubic inches of dry gas; and by the simple rule of proportion, therefore, it will be found that 100 cubic inches of such gas, when dried and at mean temperature and pressure, will weigh 46·603 grains.

"It is not necessary in this experiment that the globe or flask be perfectly exhausted of air before the gas be admitted, all that is necessary in that respect being, that the quantity of gas which enters, and the corresponding increase of weight, be known. For the same reason it is not necessary that the globe be filled, provided the quantity which does enter is ascertained upon the graduation of the jar when the level is the same inside and outside; and that no alteration of the quantity in the globe be allowed before the weighing is completed. The state and quantity of the

gas are estimated *in the jar*, and it is there that the temperature and pressure should be attended to. It is essentially necessary that the temperature of the globe over the water should have been steady for some time before the experiment be made, and that it does not change until the gas has entered the globe and the stop-cock is securely closed. After that, a little variation of temperature is of no consequence, so that nothing passes into or out of the globe until the conclusion of the experiment. The globe, as before said, should be clean and dry."

CHAPTER VIII.

THE DETERMINATION OF SPECIFIC GRAVITY.

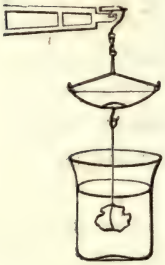
Bodies which are of uniform bulk may vary in density, and thus give rise to a difference in their specific gravity,—the relation of their weight to their volume. The density of bodies is estimated by certain standards; that for solids being pure distilled or rain water (=1·000) at 62° F. The number, therefore, expressing the specific gravity of a body is the number of times it is heavier or lighter than an equal volume of water. For example, if two bodies of equal bulk differ in density in the ratio of one to two, the latter is said to have twice the specific gravity of the former, and so in proportion. Therefore, "the volumes being equal, the densities of bodies are directly as their weights; or, the weights being equal, the densities are inversely as their volumes."

"Thus, if a cubic centimetre of iron weighs 7·8, while an equal volume of water weighs only one gramme, 7·8 is the specific gravity of iron." Hence, to find the density or specific gravity of a solid substance, its absolute weight must be divided by the weight of an equal volume of water.

Specific Gravity of Solids. *By means of the Balance.*—The two principal operations for estimating the specific gravity of a solid heavier than water, are: first, to weigh it accurately in air; and, secondly, to weigh it in water. The weight at each weighing must be immediately noted in the record book.

All of the finer balances are provided with a supplementary pan (Fig. 87), for these weighings in fluids. Though necessarily but one-third the depth of the regular pans, it is accurately made so as to exactly counterbalance either of them, and when adjusted to the beam, in its stead, to maintain perfect equilibrium. The hook beneath the pan is a convenience for the suspension of the body to be weighed. This arrangement permits the weighing of the body in air, and subsequently in water, without disturbing it or the balance. The process is as follows: Suspend the body to be weighed by a very fine platinum wire or unspun silken thread, to the hook at the bottom of the supplementary pan, and adjust this dish to that side of the beam from which the regular dish has been removed to give place to it. There are substitutes for platinum and silk, but being more permeable and less capable of furnishing a very fine and strong thread, they do not afford such nice results in delicate experiments. This done, take the weight of the body in air, observing the requisite precision in WEIGHING, and note it down in the record book without delay. To take the weight in water, it is then only necessary to convey a beaker-glass containing that liquid immediately under the dish, and carefully to immerse therein the suspended body. This vessel must be of diameter sufficient to allow a free play of the body without contact with its sides. Fig. 87 represents the whole arrangement. In introducing the body into water, particularly if it presents rough surfaces, the air attaches itself in bubbles, which must be removed with either a camel's hair pencil or wooden stick. These precautions being duly observed, put the balance in action and take the weight of the body, and immediately record it. The apparent loss of weight represents the weight of the bulk of water which the body displaces, and hence we have the requisite data upon which to calculate its specific gravity, viz., its weight in air and the weight of its own bulk of water.

Fig. 87.



Thus, for example, the body weighs:—

	Grains.
In air,	373
In water,	341
Loss,	32

By following the rule, and dividing the total weight by the loss of weight in water, thus 373÷32, we have 1·165 as its specific gravity or density.

If the body is lighter than water, a weight of known magnitude and density is joined with it to sink it. The weight may be a capsule, and form a part of the furniture of the balance for this especial purpose. It should be cullendered to allow the free escape of the globules of air adherent to the body, after receiving which, it should be suspended to the short pan as before directed.

In this, as in the previous instance, the weight required to re-establish the equilibrium disturbed by the immersion of the body in water, expresses the weight of the volume of water displaced.

"The rule, therefore, is—from the difference between the weight of the two in water and their weight in air, subtract the difference between the weight of the heavy solid in air and its weight in water; the remainder is the weight of a quantity of water equal in bulk to the light solid, from which the specific gravity of the substance may be obtained by simple proportion.

"As an example, suppose the following case:—

	Grains.
1. The weight of the light solid in air,	12
2. The weight of the heavy solid in air,	22
3. The weight of the heavy solid in water,	19
4. The weight of both tied together in water,	8
Then, from the weight of both in air (12+22),	34
Deduct the weight of both in water,	8
	26
And from the remainder deduct 22—19=3,	3
Which gives the weight of the bulk of water displaced by the light body alone,	23

"The following proportion then affords the specific gravity of the body:—

As 23 : 12 : : 1· : 0·5217."

If the substance is porous or in powder, its specific gravity is better estimated by weighing it in the bottle (Fig. 89), after the precaution of disengaging all adherent globules of air; otherwise it must, in following the preceding process, be weighed in a capsule, counterpoised first in air and afterwards in water. The water also should, before being used for this purpose, be freed of any contained air by pouring it several times from one vessel to another.

When the body is soluble in water, it must be replaced by some other liquid of determined specific gravity, which is without action. Olive oil, spirits of turpentine, and alcohol, are applicable, one or the other, for most cases.

"The specific gravity of the substance is then found by the following proportion: As the density of water is to the density of the liquid used, so is the density of the substance in relation to the liquid in which it is weighed as unity, to its density compared with water as unity."

"By the above-described process, we find how much a certain quantity of fluid weighs which has the same volume with the body to be weighed, and when once the specific gravity of the fluid is known, it is necessary to ascertain the weight of an equal volume of water."

"Let it be assumed, that a piece of salt, which is insoluble in oil of turpentine, weighs 0·352 gram., and displaces when put into the glass 0·13 gram. of oil of turpentine. The specific gravity of this fluid is 0·8725;

an equal volume of water will therefore weigh" $\frac{0{\cdot}13}{0{\cdot}8725}=0{\cdot}149$,

and the specific gravity of the salt is, therefore, $\frac{0{\cdot}352}{0{\cdot}149}=2{\cdot}36$.

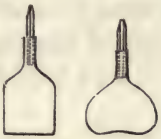
The preceding mode of taking the specific gravity of substances is founded upon the Archimedean law of hydrostatics, "that the weight of a substance in any medium is less than its absolute weight, by the weight of the bulk of the medium which it displaces, obviously its own bulk." It is, however, not wholly unobjectionable, as it is liable to give inaccurate results.

2d. *By means of a Stoppered Flask.*—In this mode of weigh-

ing, which is very available for taking the density of minute bulks of matter, and applies to bodies either heavier or lighter than water, the same attention to temperature is requisite, as in the preceding process.

The glass bottle, in which the body is to be weighed, is of form as shown by Figs. 88, 89. Its stopper should be round, slightly conical, and accurately ground. To facilitate the egress of any excess of water, in case of expansion by heat, and to enable it to sink to a uniform depth in all positions, the centre of the stopper should be perforated. The precision with which the bottle and its stopper are manufactured, has an important influence in bringing out an exact result. This bottle is especially adapted for taking the specific gravity of liquids, and its capacity may be from 100 to 1000 grains of distilled water.

Fig. 88. Fig. 89.



Three weighings are required in taking the specific gravity by this mode. The flask is first filled with water, so as to exclude all air, then conveyed to the balance and accurately counterpoised. The body to be examined is then placed in the same pan with the flask, and the balance being again set in action, the weight of the body is expressed by the additional weight necessary to produce equilibrium; and that of the body and flask by the whole weight. The substance being examined, is then placed in the flask, which is again weighed, after having been wiped clean, to free it from the displaced fluid which has flowed over its sides. The third weighing is to determine the quantity of water, which is a volume equal to its own bulk, displaced by the immersed body. Having thus obtained the requisite data, we calculate as follows:

	Grammes.
The glass vessel with water weighs, ...	13·52
The body, ...	4·056
Both together, ...	17·576

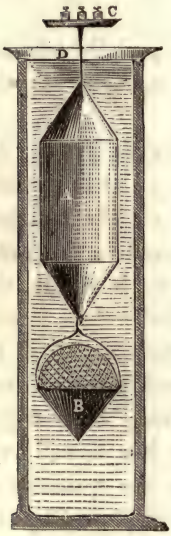
"If, after throwing the body into the bottle, putting the stopper in, and weighing the whole together, we find it to be 17·316

grammes, the weight of the water forced out by the body must be $17{\cdot}576 - 17{\cdot}316 = 0{\cdot}26$ gram.; consequently the specific gravity of the body is $\frac{4{\cdot}056}{0{\cdot}26} = 15{\cdot}6$."

3d. *By means of the Areometer.*—The areometer is an instrument which may be conveniently substituted for the balance in taking the specific gravity of solids. That known as Nicholson's is most generally used. Muller describes the apparatus and the mode of manipulating with it, clearly and concisely, as follows:

"To a hollow glass or metal body A, Fig. 90, a small heavy mass B (a glass or metal sphere filled with lead) is suspended, and superiorly there is attached to it a fine stem supporting a plate C, on which small bodies and weights may be laid. The instrument floats vertically in the water, because its centre of gravity is very low in consequence of the weight B. The instrument is so arranged that the upper part of the body A projects above the water. If now we lay the body, whose specific gravity we would ascertain, upon the plate C, the instrument will descend, and by adding additional weight, we may easily make it sink to the point *f*, marked generally by a line on the rod. We remove the mineral or other substance we have been using, and substitute in its place as many weights as will again make the instrument sink to D. If, in the place of the mineral, we have had to lay on *n* grains, the weight of the mineral is equal to *n* grains.

Fig. 90.



"If, in this manner, we have ascertained the absolute weight of the mineral, the *n* grains must be again removed, and the body laid in a basket placed between A and B. The instrument would now again sink to D if the body laid in the basket had not lost weight by being immersed in the water: we must, therefore, lay on the plate the weight *m* grains, that the body may be immersed to the mark. In this manner we obtain the absolute weight of

the body n, and the weight of an equal volume of water m; the specific gravity we seek is, therefore, $\frac{n}{m}$.

"If, for instance, we have to determine the specific gravity of a diamond, we must lay it on the plate and add sufficient weight to make the whole sink to D. If we find, after removing the diamond, that we must lay on 1·2 grains to cause the areometer to sink again to the same point, the absolute weight of the stone would be 1·2 grains. These weights must be again taken away and the diamond laid in the basket; then, in order to make the instrument sink to D, we must add 0·34 grains more; the weight of a volume of water equal in volume to the diamond is, therefore, 0·34 grains, and the specific gravity required is $\frac{1{\cdot}2}{0{\cdot}34} = 3{\cdot}53$."

Fig. 91.

4th. *By Alexander's Method.*—Analogous to the method by the bottle (p. 133), but applied inversely, is the mode proposed and employed by J. H. Alexander, wherein the precision attainable from the former by minute weighings is compensated by the largeness of the masses that can be operated with, and the resulting accuracy that, other things being equal, is always proportionate to the masses employed.

For this an ordinary bolt-head of glass, as shown in Fig. 91, is taken, and the weight of its contents of distilled water at a fixed temperature, filled to some convenient mark along the stem, to serve as a zero-point, is carefully ascertained. It is most convenient for use that this point should be adjusted so as to give the weight in question at a round num-

ber of grains, say 10,000; but in the abstract this is quite immaterial, and practically only serves to diminish the calculations. Then the stem is divided by equal additions of mercury, in the ordinary manner, into tenths, hundredths, and thousandths of the capacity of the bulb and stem, below zero. The ten-thousandths, which in ordinary cases will be between $\frac{1}{50}$ and $\frac{1}{100}$ of an inch, are too confusing to be engraved upon the stem, but can be readily estimated by the eye, or ascertained more precisely by a paper or ivory scale of equal parts.

To use this implement, the specimen whose specific weight is required is first reduced to masses of a size that will admit of passing freely through the stem, and the actual weight of the masses determined as usual. The bolt-head is then filled with water of a known temperature to any stand, and in general as near zero and above it as convenient, and the stand noted. Then the weighed masses are introduced through the stem, and the stand of the water again noted. It is manifest that the difference between the two stands is the aggregate volume of the masses expressed by the volume of water they have displaced, and the weight of these masses being already known we have both the elements whose relation determines the sp. gr. sought; or, in other words, we have the absolute weights of water and of the substance in question, both under the same volumes, and it is only necessary to divide the former by the latter to have the specific gravity sought.

Thus, to take an instance, let the aggregate weight of sundry masses of bituminous coal be 1512·5 grains; the stand of the water in the stem before their immersion be 1·0005 and after immersion 1·2115. The difference of these readings, viz., 1·2115 — 1·0005 = 0·2110, multiplied by whatever number represents the absolute weight of the unitary volume of water at zero, expresses the weight of a volume of water equal to that of the coals immersed; and in this instance as the unitary weight is 10,000 gr. we have, by merely removing the decimal point, this weight as 2110 gr. Then, this weight divided by the absolute weight of the coals, or $\frac{2110}{1512{\cdot}5} = 1{\cdot}39504$, the specific gravity sought.

Of course, this method requires the same corrections to be ap-

plied for the expansion of water as do all other methods, when the temperature of the experiment varies materially from that at which the scale of the instrument was originally adjusted. Such correction here can be the most conveniently applied by using respectively, according to the appropriate temperature, the factors in the third column of the following table as multipliers of the sp. gr. obtained. In this table, the second column gives the absolute sp. gr. of water, at various temperatures above that of maximum density, and is universally applicable in all cases of correction for temperature. The third column contains that sp. gr. corrected on purpose for the expansion of the glass bulb.

Temp.	Absolute Weight of Identical Volumes of Water.	Weight of Identical Volume of Water in Glass.
40°	1·—	1·—
45°	0·99997	1·—
50°	0·99986	1·—
55°	0·99966	0·9999
60°	0·99937	0·9997
65°	0·99899	0·9994
70°	0·99853	0·9990
75°	0·99797	0·9985
80°	0·99733	0·9979
85°	0·99660	0·9972

Thus, in the example just seen, where the unitary weight of the water had been adjusted at 40° F., if the observation had been made at a temp. of 70° F. the sp. gr. first found would have been compared with a fluid lighter by $\frac{1}{1000}$ than water at its max. density, and the corrected sp. gr. should be $1{\cdot}39504 \times 0{\cdot}9990 = 1{\cdot}39364$ to compare the coal with water at 40° F.

Of course, if an instrument of this kind should be adjusted to a unitary weight of water at some other temp., say 60° F., regard must be had in correcting to the proportion of the factors above and below such temperature and to the consequent difference of sign. For all cases above, the correction diminishes the result at first found; for all cases below, it increases that result.

In general, on the Continent of Europe, specific gravities are habitually referred to the temperature of water at its maximum density, rarely to that of melting ice, or 32° Fahr. But in England, the temperature of 62° Fahr., which is also the standard of their national weights and measures, is usually adopted; as a more practical point, and as one which, more frequently

occurring naturally, and more easily maintained artificially, tends to diminish the necessity for tabulated or special reductions. It is to be observed, however, that reductions under this system, when they have to be applied, are more complicated and more liable to errors of incaution. In America, the practice is not uniform and cannot be said to be settled, further than in the adoption by the Government of the temperature of maximum density for our national standards. This adoption, coupled with what has been already observed upon the English system, and with the manifest advantages of referring wherever we can to a *natural zero*, seems to justify the scale which has been taken in the preceding table, and to warrant the uniform reduction to the temperature of maximum density.

No account is here taken of the expansion, and consequent diminution of density, which the body itself operated on undergoes by an augmentation of temperature; both because in general the rate of such expansion is unknown at the time, and because it would be, unless the material be in very large quantities, nearly inappreciable.

Specific Gravity of Bodies Soluble in Water.—Besides this method, whose results are perfectly accurate, if the liquid employed is entirely without solvent action on the body immersed (as it may be either 1°, because of natural affinities, or 2°, because of its being previously saturated with molecules of the body in question), other modes have been devised and practised, as by Say, Leslie, and Regnault, whereby atmospheric air is substituted, and all contact with any possibly solvent liquid is avoided. The problem upon which these last modes rest is the measurement of the same volume either at constant or different temperatures, at different pressures; a problem whose performance is quite practicable. It is manifest further, that such measurement can be made irrespective of the capacity of the vessel employed, or, what is the same, just as well when said vessel is empty of all but air, as when it contains some solid body besides. If, then, such measurement be made first, and once for all when the vessel is empty, and then again at two different pressures when it contains the substance in question, the expansion at the lower pressure being altogether that of the air contained, and being less in

amount than that of the higher, because the volume of air is less by the aggregate volume of the substance in question, the difference between the two volumes reciprocally, indicated by the two lower pressures respectively, must be the volume of the substance in question; the ratio of which volume to its ascertained weight is the specific gravity.

Such is the general principle of these modes, which are entirely correct in theory, and furnish results of an accuracy proportioned to that of the apparatus and care in manipulation. Also, after the apparatus has been once accurately tared, their application requires less time than the former methods, which, in fact, is equivalent to taking two specific gravities,—one of the liquid in contact, the other of the substance immersed. But, on the other hand, these modes require, either directly or indirectly, a simultaneous reading of the barometer, and also corrections for temperature, in order to realize their full precision; which has formed hitherto an obstacle to the general introduction of any of them into ordinary laboratories.

Specific Gravity of Fluids.—There are three modes of determining the specific gravity of fluids, which take precedence in the following order, viz.: by the stoppered flask, the gravimeter, and hydrometer. The first method yields the greatest accuracy, and is that used in all nice investigations.

By the Flask.—Any small ground stoppered flask or vial will answer for the purpose. It must first be brought to the temperature of 60° F., then accurately weighed, and after the removal of the stopper, filled with distilled water of corresponding temperature. The stopper is then to be inserted, and the water that it displaces wiped from the sides of the vessel, which when dry is again carefully weighed. Its increase of weight expresses that of the bulk of water which it contains, and to save time and trouble, should be marked with a diamond upon the neck of the flask to serve for future experiments.

Glass flasks of this description are made by the manufacturers especially for this purpose. Their capacities are arranged so as to exactly receive a given quantity of distilled water expressible by weight in round numbers. The sizes vary from 100 to 1000 grs., but in each instance they have a diamond scratch on their

necks showing the measure of their contained weight of water. They have been previously described at p. 133, and are represented by Figs. 88, 89. The smaller one is most used because of greater facility in handling. Moreover the quantities of fluid under examination are generally limited, and hence the convenience of a small flask, both on this account, and because it is more easily weighed in a delicate balance.

Fig. 92.

For the more volatile liquids, and those emitting corrosive vapors, the bottle should be constructed as shown by Fig. 92. A thermometer is adjusted to the mouth, and forms the stopper; and there is an upright, lateral tube, with an accurately-fitting cap. The first enables the operator to take the temperature at the moment of the experiment, and the latter allows room for expansion of the liquid without risk of loss by overrunning or evaporation.

If the chemist prefers purchasing a flask to graduating one himself, it must be verified as above before being used, and if the weight of its contents of water does not correspond with the mark on the neck of the flask, or of the flask and water combined with that of the weight generally accompanying it as a convenient counterpoise, then the flask is not to be relied on, and should either be corrected or rejected.

In either case the flask must be thoroughly cleansed, and after each experiment should be repeatedly rinsed with distilled water, so that it may be perfectly *clean and dry* when wanted for the next operation. In emergencies, the interior may be dried by placing the flask upon the sand-bath; in this case, however, it will be necessary to allow its temperature to fall again to 62° before using it.

Distilled water at 62° F. is the standard by which to estimate the specific gravity of liquids. To take the density of a liquid,

equal bulks of it and water are taken at the balance. The flask having been graduated, its weight and that of the bulk of its contents of water are already known; it is, therefore, only necessary to fill it with the liquid under examination at 62° F., to the mark upon its neck, and after inserting the stopper, carefully weigh it. Divide the weight thus found by the weight of the water (as indicated on the flask) and you obtain the specific gravity of the liquid. For example:—

	Grains.
The clean and dry flask weighs	400
Do. do. filled with pure water, at 62° . . .	900

Deduct the first from the latter and you obtain the weight of the water = 500. Supposing, then, that the same bulk of the liquid weighs 412 grains, then 412 ÷ 500 = 0·824, its specific gravity.

If the capacity of the flask is 1000 grains of water, and one of that size, may well be used, when the stock of the liquid under examination is not limited, the process is still easier. It is then only necessary to fill it with the fluid and weigh it. The weight obtained expresses its specific gravity; thus, taking mercury for example, a bulk of that metal equal to the bulk of 1000 grains of water, is 13,500 grains, and, therefore, these latter numbers express its density, care being observed to advance the decimal point three figures to the left, if the water is taken as 1 instead of 1·000.

The vessel must, previous to weighing, be invariably wiped dry exteriorly with a linen cloth, and to avoid any communication of heat from the hands, they should be gloved.

For determining the density of very minute quantities of rare liquids, it will be necessary to have the aforementioned bottles of miniature dimension, or else to replace them by glass bulbs.

If the fluid is volatile and readily vaporizable, it should, in being raised to the proper temperature, be heated over a spirit lamp, in a test tube; taking care to keep the finger over its mouth, during the heating and cooling, so as to prevent its being unclosed.

By the Gravimeter.—The density of fluids, whether heavier

or lighter than water, may be very conveniently and precisely ascertained by the hydrostatic balance or any delicate beam, one of whose arms is furnished with a metallic ball of known weight, and so connected as to be plunged into the fluid in question. (See Fig. 93.) In the laboratory of this University, this ball is pear-shaped, of brass, heavily gilt to prevent any chemical action of the liquid upon it, and attached by the finest platinum wire, the weight of which, per inch, is also ascertained. It is manifest that the absolute weight and the volume of any body being constant, the apparent diminution of weight it sustains, upon being immersed in any fluid, becomes less, i. e., the counterpoise required becomes greater, just as the density of the circumambient fluid diminishes; and that in counterpoising such a body, the ball, for instance, just spoken of, immersed successively in fluids of different densities, we are obtaining the weights of identical volumes of the fluids respectively, and if one of those fluids be water, the technical specific gravities of all the others.

Fig. 93.

The application of these principles, and the convenience of the method itself, will be better seen by an actual numerical example of determining the specific gravity of sperm oil. In this, the temperature at the beginning and end of the observations was constant at 64·5° F.; the barometer stand 29·95 inches, so little differing from the standard as not to be worth noting for correction. The counterpoise to the ball in air was 172·60 grains; in water, 118·70 grains; in the oil, 125·19 grains. The respective differences between the first and the last two, viz., 53·90 grains and 47·41 grains, give at once the ratio of the specific gravity of the water to that of the oil, as 1 : 0·87959, which, if the circumtances in the cases of the two fluids were the same, would be the final result. In point of fact, however, the circumstances were not the same; for the immersion of the platinum wire, which weighed 0·047 grains per inch, was in the water 0·5 inch, and in the oil 0·3 inch; leaving 0·2 inch of wire, corresponding to 0·0094 grains in absolute weight, less in the oil than in the water. This surplus weight, of course, had to be borne by the counterpoise, which it increased by its own amount; leaving out

of the view the remote correction for the different displacement by the constant mass of the platinum of varying volumes of water and oil. It is, therefore, to be subtracted from the oil counterpoise, or, what is the same, added at once to the 47·41 grains loss of weight in oil; making 47·4194 grains to be divided by 53·9 grains, the loss in water, and resulting in a quotient of 0·87977, the specific gravity of oil at 64·5° F., that of water, at the same temperature, being considered unity.

But water is systematically unity only at its maximum density, say 40° F., and oil increases in density 0·000423 for every degree downward, at least to that temperature, and probably still lower, until near its freezing-point. If, therefore, oil be taken for unity at 40° F., its proportionate density at 64·5° F. will be $1 - (0{\cdot}000423 \times \overline{64{\cdot}5^\circ - 40^\circ}) = 0{\cdot}98964$. That of water at 64·5° F., may be ascertained with sufficient precision from the table just now given, by taking proportional parts between the temperatures and densities there given. Thus, the difference between 60° and 65° is 5°, of which the difference between 65° and 64·5° is the tenth part; also, the difference between the specific gravity corresponding, or 0·99937 and 0·99899 is 0·00038, of which the proportional tenth part is 0·000038, or, say 0·00004 to be added to 0·99899, making the density of water at 64·5° = 0·99903. The final density of oil, then, at 40° F., will be to the density at 64·5° F., in the inverse ratio of these proportionate numbers; or $\frac{99903}{98964} \cdot 0{\cdot}87977 = 0{\cdot}88812$, the ultimate specific gravity of oil compared with water as 1·, both being at the temperature of 40° F. Such is the mode of applying the reductions in question, which belong universally to all methods of determining specific gravities.

By Nicholson's Areometer.—"The specific gravity of liquids may also be determined by Nicholson's areometer, Fig. 90. As the instrument always sinks so far that its weight, added to the weight upon the plate, is equal to the mass of liquid displaced, we may, by the aid of this instrument, ascertain how much a definite volume of water weighs. It is necessary, however, to know the weight of the instrument itself. Suppose this weight to be n, we must lay on some additional weight to make the instrument sink to D; if we designate this addition by a, then is $n + a$ the weight of water displaced.

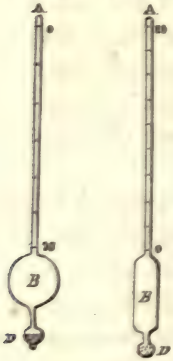
"If we immerse the instrument in another liquid, we must lay on another weight b in the place of a, to make the whole sink to D; b will be greater than a if the liquid be denser, and less than a if it be lighter than water. The weight of the liquid displaced is $n + b$; but its volume is exactly as great as the volume of the mass of water, whose weight is $n + a$, because the areometer has sunk equally deep in both cases.

"Suppose the instrument weigh 70 grains, we must add 20 grains to make it sink in water, and 1·37, that it may sink to the point f in spirits of wine; then the specific gravity of spirits of wine is $\frac{70 + 1{\cdot}37}{70 + 20} = 0{\cdot}793$."

By the Hydrometer.—Hydrometers do not give very accurate results, but they are convenient when time is an object, and no great precision is requisite. Their action is based upon the hydrostatic law, "*that a floating body displaces its own weight of the liquid in which it swims.*"

The instrument consists of a glass stem A, with an air-bulb, B, beneath, properly ballasted with mercury or shot, D. The depth to which the hydrometer will sink in a liquid is proportioned to its rarity, for the denser the liquid, the less of it will be displaced. A properly graduated scale inserted within the stem or spindle, allows the appreciation of the density of a liquid by the greater or less depth to which it sinks therein. The form of this instrument is shown by Figs. 94, 95. They are constructed with different scales, according as they are intended for liquids rarer or denser than water. The scales for those which are rare run from zero (at the bottom of the stem) upwards. The graduation of the scale for liquids denser than water is reversed.

Fig. 94. Fig. 95.



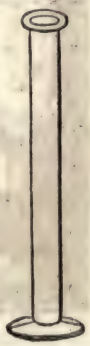
Areometers are variously graduated for different liquids, thus—

Those for ether	mark	upwards	from		10 to 50°
" " spirits	"	"	"		10 to 80
" " salts	"	downwards	"		0 to 40
" " acids	"	"	"		0 to 75
" " syrups	"	"	"		0 to 36

The following table shows the specific gravity numbers corresponding with Baumè's areometric degrees:—

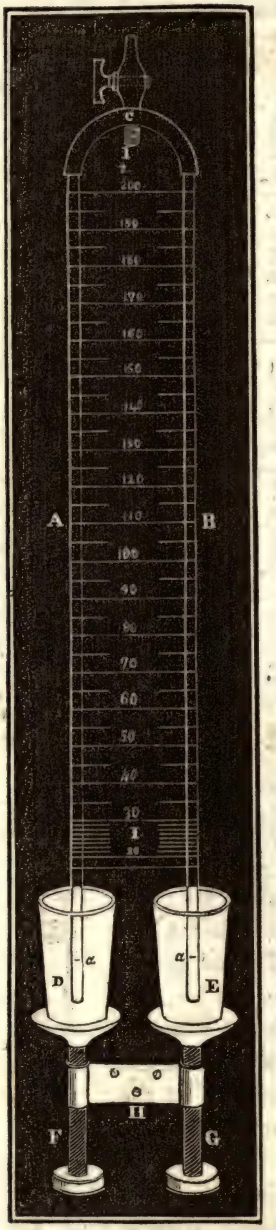
LIQUIDS DENSER THAN WATER.						LESS DENSE THAN WATER.			
Degrees.	Specific Gravity.	Degrees.	Specific Gravity.	Degrees.	Specific Gravity.	Degrees.	Specific Gravity.	Degrees.	Specific Gravity.
0	1·0000	26	1·2063	52	1·5200	10	1·0000	36	0·8488
1	1·0066	27	1·2160	53	1·5353	11	0·9932	37	0·8439
2	1·0133	28	1·2258	54	1·5510	12	0·9865	38	0·8391
3	1·0201	29	1·2358	55	1·5671	13	0·9799	39	0·8343
4	1·0270	30	1·2459	56	1·5833	14	0 9733	40	0·8295
5	1·0340	31	1·2562	57	1·6000	15	0·9669	41	0·8249
6	1·0411	32	1·2667	58	1·6170	16	0·9605	42	0·8202
7	1·0483	33	1·2773	59	1·6344	17	0·9542	43	0·8156
8	1·0556	34	1·2881	60	1·6522	18	0·9480	44	0·8111
9	1·0630	35	1·2992	61	1·6705	19	0·9420	45	0·8066
10	1·0704	36	1·3103	62	1·6889	20	0·9359	46	0·8022
11	1·0780	37	1·3217	63	1·7079	21	0·9300	47	0·7978
12	1·0857	38	1·3333	64	1·7273	22	0·9241	48	0·7935
13	1·0935	39	1·3451	65	1·7471	23	0·9183	49	0·7892
14	1·1014	40	1·3571	66	1·7674	24	0·9125	50	0·7840
15	1·1095	41	1·3694	67	1·7882	25	0·9068	51	0·7807
16	1·1176	42	1·3818	68	1·8095	26	0·9012	52	0·7766
17	1·1259	43	1·3945	69	1·8313	27	0·8957	53	0·7725
18	1·1343	44	1·4074	70	1·8537	28	0·8902	54	0·7684
19	1·1428	45	1·4206	71	1·8765	29	0·8848	55	0·7643
20	1·1515	46	1·4339	72	1·9000	30	0·8795	56	0·7604
21	1·1603	47	1·4476	73	1·9241	31	0·8742	57	0·7556
22	1·1692	48	1·4615	74	1·9487	32	0·8690	58	0·7526
23	1·1783	49	1·4758	75	1·9740	33	0·8639	59	0·7487
24	1·1875	50	1·4902	76	2·0000	34	0·8588	60	0·7449
25	1·1968	51	1·4951			35	0·8538	61	0·7411

Fig. 96.



The hydrometer is used with a tall glass jar (Fig. 96), which serves as a recipient for the liquid to be tested. After having perfectly cleansed it of grease and dirt with a cloth, it is to be placed in the jar, and the liquor, first brought to 62° F., added. When it becomes stationary, note the degree at which it stands. For verification, raise it an inch or more out of the liquid, and then let it gradually sink back again. If it reaches the same point as before, the first observation was correct. In reading the divisions on the scale, do not take that line where the liquid rises in wetting the stem of the instrument, but note it at the

Fig. 97.



real level, which is the curvature produced by the ascending motion of the liquid against the sides of the spindle.

Hydrometers graduated by Baumè's process are generally used.

By Ham's Method.—This requires the use of a special apparatus, by means of which the air is made to take the place of the balance. It is said to yield accurate results with great promptness. It consists of two glass tubes, A and B, Fig. 97, 20 to 24 inches long, and with bores of one-fourth to three-eighths of an inch diameter. A semicircular brass tube and cock C connect them at the top; and their lower ends, which are left open, dip into two glass vessels or beakers D E, one of which is to contain distilled water, and the other the liquid under examination. These latter are supported by stands kept in adjustment by the milled-headed screws F G, and the bracket and nuts H. The scale I I is divided into two hundred parts. By increasing the number of divisions or degrees to 2000 the instrument may be rendered still more exact.

Distilled water being poured into one of the beakers, and the liquid to be tested in the other, air is to be drawn from the tubes by attaching a syringe to the cock C, until the lightest fluid is nearly at the top of one of the tubes. The surfaces of the two fluids in the vessels D and E are then equalized, or brought to *a a* by raising or depressing the stands by means of the screws, as may be required. The heights of the fluids in their respective tubes will im-

mediately show their relative densities, convertible into water at 1000 by simple proportion.

The liquids should be at 60° F., or some uniform temperature approximating that point, at the time of the experiment.

SPECIFIC GRAVITY OF GASES.—The extreme lightness of gases and vapors renders it inconvenient to compare their weight with that of an equal bulk of water, and consequently air is taken as the standard.

The mode of taking these specific gravities is thus concisely and clearly described by Parnell: "From the careful experiments of Dr. Prout, it appears that 100 cubic inches of atmospheric air deprived of carbonic acid and aqueous vapor weigh 31·0117 grains, at 30 inches of the barometer, and at the temperature of 60° F.; from which observation it is easy to calculate the absolute weight of any bulk of a gas from its specific gravity. Thus the specific gravity of chlorine is found to be 2·47; to find how much 100 cubic inches of that gas weigh at mean temperature and pressure, we make use of the proportion,

As 1 : 2·47 : : 31·01 : 76·59;

therefore 100 cubic inches of chlorine weigh 76·59 grains.

The simplest method of obtaining the specific gravity of a gas is the following:—The object is to ascertain the weight of a bulk of gas equal to the bulk of a known weight of air. For this purpose, a light glass globe, furnished with a stop-cock, is very accurately weighed, when full of air; then exhausted of its air, by connecting it with an air-pump, and weighed in the vacuous state. The weight of the air withdrawn by the exhaustion is thus ascertained. The globe, still vacuous, is connected with a jar containing the gas (Fig. 98) which is to be weighed, at the water or mercurial trough; the jar having a stop-cock at its top, into which the stop-cock of the globe can be screwed air-tight. On gently opening both stop-cocks, a quantity of gas rushes from the jar into the exhausted globe, equal in bulk to the air withdrawn by the exhaustion, if the surface of the liquid within the jar be brought to the level of that without in the

Fig. 98.

trough, and the temperature of the air and the barometric pressure have not varied during the experiment. The stop-cock being closed, the globe is detached from the jar, and weighed. The difference between its weight when containing the gas, and when vacuous, is the weight of a bulk of the gas equal to the bulk of air whose place it occupies, the weight of which has already been determined.

Suppose the globe to lose 10·33 grains by exhaustion of air, and, when exhausted, to gain 15·78 grains by admitting carbonic acid gas; then, assuming 1· as the density of air, we have the proportion,

As 10·33 : 15·78 : : 1 : 1·527;

the specific gravity of carbonic acid gas is, therefore, 1·527.

Although thus simple in principle, the operation in its details is one of extreme delicacy. From the facility with which gases undergo a change in their bulk through variations of temperature and pressure, it is obvious that if the temperature and barometric pressure vary during the course of the experiment, corrections must be made. As an illustration of the necessary corrections, suppose the bulk of air to weigh 12 grains at the temperature of 60° F., and under a pressure of 30 inches bar.; and the same bulk of the gas whose density is required to weigh 20 grains, but at the temperature of 50° F., and under a pressure of 28 inches bar. The points to be determined here are two:—

1. Considering the volume of the air withdrawn and the gas admitted as 1·, at the observed temperatures and pressures, what would be the volume of the gas at the temperature and pressure at which the air was weighed?

And, 2, having obtained that volume, what is the corresponding increase or reduction in the *weight* of the gas?

Performed according to rules which are given in the note below,* the results of these calculations are as follows:—

* "1. *For Changes in Bulk by Pressure.*—The volume which a gas should possess at one pressure may be calculated from its known volume at another pressure, by the use of the following proportion:—As the pressure to which the gas is to be corrected is to the observed pressure, so is the observed volume to the volume required. In the example in the text (*b*), the pressure to which the gas is to be reduced is 30 inches, the observed pressure 28 inches, and the volume is 1·019. Then, as 30 : 28 : : 1·019 : 0·951.

"2. *For Changes in Bulk by Temperature.*—From the very recent experiments

(*a*) A volume of gas equal to 1· at 50° F. is equal to 1·019 at 60° F.

(*b*) A volume of gas equal to 1·019 at 28 inches of the barometer is equal to 0·951 at thirty inches.

A volume of the gas, therefore, equal to 0·951 weighs 20 grains; a volume of air equal to 1· at the same temperature and pressure weighing 12 grains. Then, if 0·951 vol. weighs 20 grains, 1 vol. should weigh 21·03 grains; and

As 12 : 1 : : 21·03 : 1·75;

1·75 is, therefore, the density required.

The state of dryness of a gas is another circumstance which interferes with its volume; for which reason, due care should be taken to insure either the perfect dryness of the gas, or its complete saturation with moisture. In the latter case, the temperature must be noticed, and the observed volume reduced according to the proportion of aqueous vapor capable of existing in the gas at the observed temperature. The proportions of vapor by volume contained in one vol. of the saturated gas for temperatures between 40° and 80° F. are expressed in the table at page 127. A cubic inch of aqueous vapor corrected to the temperature of 60°, and at a pressure of 30 inches, weighs 0·1929 grains.

The preceding method of obtaining the density of a gas still requires a slight correction from another circumstance, when the temperature and pressure differ considerably at the time of weighing the air and at the time of weighing the gas; but one so trifling that it may, in general, be neglected. The necessity of this cor-

of M. Regnault, it appears that a volume of gas expands by heat $\frac{1}{459}$ of its bulk for each degree Fahrenheit. Hence, the volume of a gas at 0° F. being 1, at any higher temperature it is found by the formula $1 + \frac{\text{Temp. Fah.}}{459}$. The determination of the volume of a gas at one temperature from its known volume at another temperature may be attained by the following formula:—Let t be the temperature Fahrenheit at which the volume of the gas is observed; t' the temperature Fahrenheit to which the volume of the gas is to be reduced; x the observed volume at t; and x' the volume at t' required;

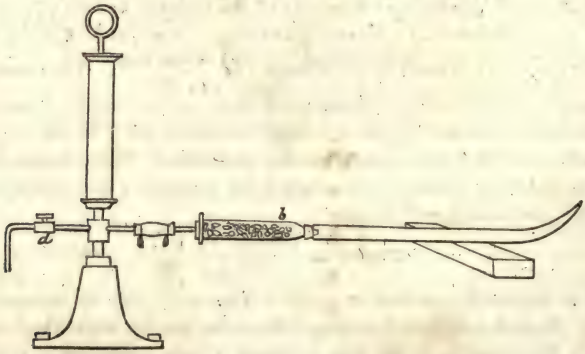
$$\text{Then } x' = \frac{(459 + t') \times x}{459 + t}.$$

"3. It is frequently necessary to combine corrections both for temperature and pressure. In such a case, as in the example in the text, the reduction of volume is first made for temperature, and that corrected volume is afterwards reduced according to the pressure.

rection arises from the impossibility of obtaining a perfect vacuum in the globe; and the remaining small quantity of air may occupy a different space when weighed with the gas, to that which it occupied when the globe was weighed with air; and consequently the bulk of the gas admitted into the globe is not the same as the bulk of the air withdrawn. If the amount of rarefaction of the air in the exhausted flask is observed, by means of a barometer gauge attached to the air-pump, the amount of the remaining air may be calculated when the weight of the quantity withdrawn is ascertained; then the alteration to which it would be subject in bulk by changes of temperature and pressure may also be estimated, and a due allowance made on the bulk of the gas admitted into the globe."

When the gas is corrosive in its action, as in the case of chlorine, the balloon with its metallic cock must be replaced by a glass flask, with a nicely-fitting ground stopper. This flask is to be adjusted to a drying-tube connected with the vessel in which the chlorine is generated. The bent end of the drying-tube entering the flask should reach to its bottom. The disengaged gas, in passing through the tube, parts with its moisture, and reaching the flask descends to the bottom, and displaces the air, which is expelled through the interstices at the mouth around the tube. When the chlorine itself begins to escape, it is evidence that all the air has been displaced, and the flask is then to be slowly and gently detached from the apparatus and hermetically closed with its ground stopper.

Fig. 99.

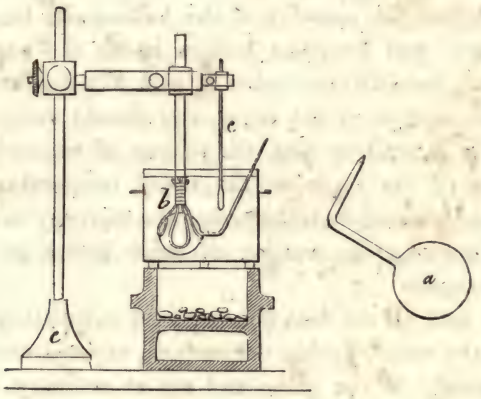


SPECIFIC GRAVITY OF VAPORS.—The following method, devised

by Dumas, is applicable to all substances vaporizing, without decomposition, at temperatures less than the fusing-point of hard glass.

Take a glass globe of about 12 to 16 oz. capacity, with a long slender neck, wash it with distilled water, and carefully dry it, either by slight warmth or by means of the exhausting syringe and a tube filled with chloride of calcium. (Fig. 99.) After the balloon is perfectly dry, its neck is to be drawn out to a narrow tube, 6 or 8 inches long, and bent nearly at a right angle, as shown at *a*, Fig. 100. The tip is then to be removed with a file,

Fig. 100.



and the mouth of the tube rounded (not closed) over the blowpipe flame. The globe full of air is now weighed, with great precision, and afterwards warmed to expel a portion of its air. This done, and the temperature and barometric pressure having been observed, its beak is immediately dipped into the liquid or melted* solid matter, and as the air within contracts by the cooling of the bulb, which may be hastened by dropping ether on its exterior, the fluid is drawn up. When the requisite quantity, say 100 to 150 grains, has entered, the globe is at once enclosed in a wire basket *b*, Fig. 100, and introduced into a cast iron kettle containing water for the bath, when the temperature is not to

* If the solid body is not fusible, a given weight of it is introduced into the globe, previously dried. The neck is then drawn out, the end removed and placed in the balance. By deducting its weight from that of the whole balloon, you obtain the weight of the balloon full of air.

exceed 212° F. Solution of chloride of calcium must be used for temperatures near 250°, neat's-foot oil when 300° is required, and metal baths for higher degrees. The wooden support *e*, to an arm of which is suspended the thermometer *c*, keeps the globe firmly fixed in the bath.

The bath is brought to ebullition, and as soon as it rises above the boiling-point of the substance, a jet of vapor escapes through the tube, and as soon as it ceases, the point is quickly sealed up over the blow-pipe flame, observing at the same time the temperature of the bath and the barometric pressure.

The globe thus closed is then withdrawn from the bath, washed, dried, and again weighed.

To determine the capacity of the balloon, its tube is dipped into mercury, and its point broken under the surface of the metal, which immediately rushes in and fills the vacuum caused by the condensation of the vapor, and should occupy the whole interior. It is evident that the volume of mercury represents the volume of the vapor at the noted temperature, and this volume is determined by transferring the mercury to a graduated tube, and marking the number of cubic inches or centimetres which it occupies.

We thus have all the data necessary for calculating the specific gravity of the vapor, having determined, experimentally,—

"1. The weight of the globe and air at ordinary temperature and pressure;

"2. The weight of the globe and vapor filling it at the temperature of the bath, and under ordinary pressure; and,

"3. The capacity of the globe.

"Having these results, we obtain by calculation,—

"1. The weight of the empty globe (by knowing the capacity of the globe, the weight of the air filling it can be calculated, which, deducted from the weight of the globe and air, leaves the weight of the globe when vacuous);

"2. The weight of vapor filling the globe at the temperature of the bath (by deducting the weight of the empty globe from the weight of the globe and vapor); and,

"3. The weight of air filling the globe at the temperature of the bath, and at the pressure at which the globe was sealed with the vapor.

"The last calculation is made according to rules given in the note, pp. 147 and 148; having performed which, the density of the vapor required is obtained by the simple proportion,—As the weight of air filling the globe at the temperature of the bath is to the weight of vapor filling the globe at the same temperature, so is 1 to the density required."

It is necessary to remark, that in the instances of organic substances which are sensitive to the decomposing influence of the air at the temperature to which their vapors must be heated, in order to obtain constant densities, the glass globe should be filled with carbonic acid gas previous to heating the bath. The manipulations, thereafter, are as already directed.

The following table of the densities of a large number of substances, and for which we are indebted to Th. J. Herapath (*Chemist*, vol. 4), will be found very convenient for reference. It comprises the most reliable results; and in instances of doubt or discrepancy, conflicting numbers are also given, with a note of interrogation affixed to the most questionable. The * attached to certain names is intended to indicate that the authority cited is not responsible for the numbers, as they were merely quoted from those writers.

TABLE OF DENSITIES OR SPECIFIC GRAVITIES.

Substances.	Density at 60° F.	Authority.
Acadiolite,	2·0 to 2·1	Dr. Thomson.
Acanticone,	3·43 to 3·46	——
Acetal,	0·821 at 72°	Stas.
"	0·842	Liebig.
Acetic acid, monohyd.,	1·063	Mollerat.
3-hyd.,	1·085	Ure.
commer.,	1·025	Brande.*
of L. Ph.,	1·063 to 1·068	Gray.*
Acetone,	0·75	Trommsdorf.
"	0·78	Chenevix.
"	0·792 at 64°	Liebig and Dumas.
"	0·822	L. Gmelin.
"	0·925	Löwig.
Acetum distillatum of E. and D. Ph.,	1·005	Gray.*
Achirite,	3·278	W. Phillips.
Achmite,	3·398	Dr. Thomson.
Acidum hydrochl. L. Ph.,	1·16 at 62°	
E. Ph.,	1·17 at 60°	
D. Ph.,	1·16 at 60°	
Acidum, hyd. dil. E. Ph.,	1·05 at 60°	
D. Ph.,	1·08	
Acidum, hydrocyan.,	0·998	
A. nitricum, L. Ph.,	1·50 at 62°	
E. Ph.,	1·50 at 60°	
A. nit. dil. L. Ph.,	1·08 at 62°	
E. Ph.,	1·077 at 60°	
D. Ph.,	1·0[illegible] at 60°	
A. phosphor. dil.,	1·064	
A. sulph. L. Ph.,	1·845 at 62°	
D. & E. Ph.,	1·845 at 60°	
A. sulph. dil. L. Ph.,	1·110 at 62°	
E. Ph.,	1·090 at 60°	
D. Ph.,	1·084	
Actinolite,	3·2 to 3·5 (?)	
glassy,	2·95 to 3·93	L. Gmelin.
Ærosite,	5·8 to 5·9	Bonsdorff.
Æschynite,	5·55	Dr. Thomson.
Æther, acetic,	0·89	Liebig.
benzoic,	1·054 at 50°	Graham.*
boracic,	0·885	Ebelmen.
butyric,	0·902 at 32°	Pierre.
carbonic,	0·965 at 66°	Ettling.
cinnamic,	1·131	Marchand.
citric,	1·142	Malaguti.
formic,	0·912	Liebig.
hippuric,	1·043 (?)	Stenhouse.
iodic,	1·34	Johnson.
mucic,	1·17 (?)	Malaguti.
nitric,	1·112	Millon.
nitrous,	0·947 (?)	Graham.*
œnanthic,	0·862	Pelouze.
oxalic,	1·092	Graham.*
pyrocitric,	1·050	Malaguti.
pyromucic,	1·297	"
salicylic,	1·097	Baly.
silicic,	0·932	Ebelmen.
succinic,	1·036	D'Arcet.
sulphuric,	0·6974	Löwig.
(*oxide of ethyl*),	0·715 at 68°	Graham.*
sulphurous,	1·085	Ebelmen.
valerianic,	0·894	Grotte and Otto.

Substances.	Density at 60° F.	Authority.
Æ. nitrosus. D. Ph.,	0·90 at 60°	
Æ. sulph. L. Ph.,	0·75 at 62°	
D. Ph.,	0·766 at 62°	
E. Ph.,	0·735 at 60°	
Ætherole,	0·917	Graham.*
Æthyl, bromide,	1·473 at 32°	Pierre.
chloride,	0·874 at 42°	Brande.*
iodide,	1·92	Marchand.
sulphide,	0·842	Regnault.
Agalmatolite,	2·815	Klaproth.
"	2·895	Thomson.
Agate,	2·35 to 2·66	Cresy.*
Alabaster,	2·31 to 2·326	Beudant.
Albite,	2·608 to 2·619	G. Rose.
Alcohol,	0·793	Löwig.
absolute,	0·7938	Drinkwater.
A. absolutum, E. Ph.,	0·796 at 60°	
P. C.,	0·7964	
D. Ph.,	0·810	
L. Ph.,	0·815	
Aldehyde,	0·79	Gluckelberger.
Allanite,	3·119 to 3·80	Dr. Thomson.
Algerite,	2·78	Crossley.
Allantois, liq. of,	1·007	Vauquelin.
Alluandite,	3·468	Damours.
Alum,	1·714	Muschenbrock.
"	1·724	Kopp.
ammon.,	1·626	"
chrome,	1·848	"
Alumina,	4·154	Filhol.
Aluminite,	1·705	Stromeyer.
Alum-stone, massive,	2·752	Thomson.*
"	2·587	Haüy.
Allophane,	1·85 to 1·89	Stromeyer.
Amalgam, native,	13·755	Haidinger.

Substances.	Density at 60° F.	Authority.
Amazon-stone,	2·581	H. Rose.
Amber,	1·06 to 1·07	Brande.*
Amber,	1·08 to 1·085	Ure.*
Ambergris,	0·78 to 0·92	Brisson.
Amblygonite,	3·0 to 3·04	Breithaupt.
Amethyst, common,	2·75	Moseley.*
oriental,	3·391	"
Amianthus,	1·551	Thomson.*
"	2·313	Moseley.*
Ammonia, liq. anhyd.,	0·760	Faraday.
sat. aqueous solu. of,	0·850	Brande.
bicarb. of,	1·586 at 39·1°	Playfair and Joule.
muriate of,	1·533	" "
nitrate of,	1·58	" "
sulph. of,	1·75	" "
Ammoniæ, aqua, E. Ph.,	0·96 at 60°	
D. Ph.,	0·95 at 60°	
Am. liquor, L. Ph.,	0·96 at 62°	
fortior,	0·882 at 62°	
Amnios, liq. of,	1·005 to 1·009	
Amphodelite,	2·763	Nordenskiöld.
Amyle,	0·77 at 52°	Frankland.
oxide,	0·779 at 72°	Riechker.
Analcime,	2·068	Haidinger.
"	2·278	Thomson.
Anatase,	3·857	Haüy.
"	3·826	Mohs.
Andalusite,	3·13 to 3·31	Thomson.*
Andesine,	3·733	Abich.
Anglarite,	1·787	Berthier.
Anglesite,	6·298 to 6·659	Thomson.*
Anhydrite,	2·89 to 2·94	Haidinger.
Aniline,	1·028	Fritsche.
Anorthite,	2·65 to 2·76	H. Rose.
Anthophyllite, hydrous,	2·911	Thomson.

Substances.	Density at 60° F.	Authority.
Anthracite,	1·559 to 1·630	W. R. Johnston.
"	1·61 to 1·69	T. Herapath.
Antigorite,	2·622	Weiser.
Antimonic acid,	3·78	Playfair and Joule.
Antimonious acid,	4·074	" "
Antimony, red,	4·09	Klaproth.
"	4·5 to 4·6	Mohs.
" sesquisulph.,	4·75	Karsten.
" "	4·62	Mohs.
" "	4·52	Haüy.
Antrimolite,	2·096	Thomson.
Apatite,	3·1 to 3·23	Haüy.
Aphrodite,	2·73	Svanberg.
Aphthitalite,	1·73	Phillips.
Aplomb,	3·45	Cresy.*
Apophyllite,	2·359	Thomson.
"	2·335	Haidinger.
Aqua distil.,	1·000	
baryta muriatis,	1·23	
calcis muriatis,	1·202	
potassæ, E. Ph.,	1·072	
D. Ph.,	1·080	
pot. carbh.,	1·320	
sulph.,	1·117	
sodæ carb.,	1·024	
Aqua marina,	2·65 to 2·76	Cresy.*
Arcanson,	1·083	"
Arfwedsonite,	3·369	Haidinger.
Argillite,	3·609 to 3·68	Cresy.*
Arkansite,	3·892 to 3·949	Rammelsberg.
Arragonite,	2·885 to 2·930	Stromeyer.
"	2·92	Bournon.
"	2·927	Biot.
"	2·932	Haidinger.
Arsenic, pt. sulph.,	3·40	Brande.*

Substances.	Density at 60° F.	Authority.
Arsenic, ter-sulph.,	3·459	Karsten.
acid,	3·40	Brande.*
"	3·92 at 39·1°	Playfair and Joule.
"	4·25	Filhol.
Arsenical pyrites,	6·127	Thomson.*
Arsenious acid,	3·884	Filhol.
"	3·702	Karsten.
"	3·698	Dumas.
"	3·695	Guibourt.
"	3·69 to 3·71	Leonhard.
Arsenio, siderite,	3·52	Dufrénoy.
Asbesterite,	3·0 to 3·31	Thomson (?).
Asbestos,	0·681 to 0·998	Cresy.*
saturated with water,	1·25 to 1·35	"
Asparagin,	1·52	Graham.*
Asphalt,	1·073 to 1·16	Thomson.*
"	1·205	Klaproth.
Asphaltum, cohesive,	1·45 to 2·06	Cresy.*
compact,	1·07 to 1·165	"
Atacamite,	4·43	Thomson.*
Augite,	3·297	"
"	3·226 to 3·777	Cresy.*
Automolite,	4·261	Ekeberg.
Aventurine,	2·643 to 2·666	Cresy.*
Axinite,	3·271	Haidinger.
Azure-stone or Lazulite,	2·772 to 2·945	"
BABINGTONITE,	3·35 to 3·5	
Ball or "Stiff,"	2·558	Couper.
Balsam, Copaiba,	0·95	Schonberg.
" "	0·996	Ure.*
Mecca,	0·876	Bonastre.
of Peru,	1·15	Thomson.*
Barium, chloride, crys.,	2·664	Filhol.
do. fused,	3·75	"

Substances.	Density at 60° F.	Authority.
Barium, perox. of,	4·96 at 39·1°	Playfair and Joule.
Barley, English,	1·25 to 1·33	Ure.*
Scotch,	1·227 to 1·265	"
Baryta,	5·456	Filhol.
	4·986 at 39° F.	Playfair and Joule.
	4·733	Karsten.
hydrate; (1 at. HO),	4·495	Filhol.
hydrate; (9 at. HO),	1·656	"
carb. of,	4·301	Mohs.
(*Witherite*),	4·330	T. Herapath.
	4·292	Haüy.
" artif.,	4·565	Filhol.
nitrate of,	3·200	"
sulph. of,	4·4714	Mohs.
(*Baroselenite*),	4·472	Thomson.*
	4·483	T. Herapath.
artif.,	4·535	H. Rose.
Baryto-calcite,	3·868	Thomson.
fluate of lime,	3·750	Smithson.
Basalt,	2·422 to 3·000	
Basanite,	2·59 to 2·64	Hofmann.
"	3·00	Moseley.
Baudisserite,	2·808	Breithaupt.
"	2·915	Klaproth.
"	2·950	Stromeyer.
Beaumontite,	2·250	Delesse.
Beer:—		
Bock-bier,	1·013 to 1·020	
Burton, 1st S.,	1·111 to 1·112	Richardson.
2d S.,	1·097 to 1·111	"
3d S.,	1·077 to 1·092	"
"	1·047	L. Hoffmann.
Com. Ale,	1·070 to 1·073	Richardson.
Pale Ale,	1·0088 at 52°	L. Hoffmann.
Allsop's,	1·01	Dr. Ure.
Pale Ale, Bass's,	1·006	Dr. Ure.
Porter,	1·050	Richardson.
best,	1·072	"
Stout,	1·055 to 1·065	"
Table-beer,	1·033 to 1·039	"
Benzoin, gum,	1·063 to 1·093	Ure.*
Benzole,	0·850	Mansfield.
Benzule, chl.,	1·106	Graham.*
"	1·196	Brande.*
Beraunite,	2·878	Breithaupt.
Beryl, oriental,	3·549	Moseley.*
occidental,	2·723	"
Berzelite,	7·0 to 7·1	Thomson.
Bezoar, oriental,	1·463	Berthollet.
Bile, human,	1·025 to 1·027	Berzelius.
"	1·025 to 1·030	Dr. Garrod.
Biotine,	3·110	Monticelli.
Bismuth, blende,	5·912 to 6·006	Thompson.
glance,	5·85 to 6·55	"
native,	9·737	"
needle ore of,	6·100	Chapman.
"	6·125	John.
"	6·757	Frick.
nitrate, cr.,	2·736	Playfair and Joule.
ochre,	4·361	Brisson.
oxide of,	8·179	Playfair and Joule.
"	8·200	Brande.*
sulphide,	7·000	Karsten.
"	7·591	W. Herapath.
"	7·807	Wehrle.
telluride,	7·500 to 8·400	"
"	7·514	Baumgartner.
Bitumen,	1·073 to 1·160	Thomson.
from Judæa,	1·104	Cresy.*

Substances.	Density at 60° F.	Authority.
Bitumen, elastic,	0·9053 to 1·2330	Hatchett.
Blende,	4·049	Thomson.*
"	3·70 to 4·20	Ure.*
"	4·063	T. H. Henry.
Blood, human,	1·050	Thomson.
"	1·053	Richardson.
"	1·0527	Haller.
"	1·0570	Berzelius.
"	1·058 to 1·062	Becql. and Rodier.
serum of,	1·0257 to 1·0264	Richardson.
"	1·027 to 1·029	Berzelius.
"	1·047 to 1·050	E. Davy.
crassamentum of,	1·245	Dr. Jurin.
Blue-spar,	3·021 to 3·046	
Bondite,	3·571	Thomson.
Bones,	1·777 to 2·034	
Boracic acid,	1·480	Brande.*
vitreous,	1·75	Breithaupt.
"	1·803	Davy.
"	1·812	Th. Herapath.
Boracite,	2·938 to 2·974	
Borax,	1.692	Filhol.
"	1·703	Th. Herapath.
octohedral,	1·815	Brande.*
"	1·8233	Th. Herapath.
vitreous,	2·3670	Filhol.
"	2·3802	Th. Herapath.
sat. solu.,	1·0211	"
Bornine,	7·500 to 8·440 (?)	Wehrle.
Boron,	2·000	Brande.*
Botryogine,	2·039	Berzelius.
Botryolite,	2·885	Klaproth.
Boulangerite,	5·69 to 5·97	Rammelsberg.
Bournonite,	5·776	Hatchett.
Brandy, Armagnac,	0·922	Ure.*
Brandy, Cognac,	0·935	Ure.*
Brass,	7·9 to 8·9	Brande.
"	7·82 to 8·73	Ure.
cast,	8·10	Watson.
sheet,	8·52 to 8·62	Ure.*
plate,	8·441	Tredgold.*
wire,	8·49 to 8·73	Ure*.
"	8·544	Tredgold.*
Braunite,	4·818	Thomson.*
Breithauptite,	3·80	Wälchner.
Brewsterite,	2·432	Thomson.
Brick, common,	1·557 to 2·000	Tredgold.
red,	2·168	Rennie.
pale-red,	2·085	"
London,	1·845	Tredgold.
Welsh fire,	2·408	"
Bromal,	3·340	Thomson.*
Bromine,	2·966	Graham.*
"	3·060	Kopp.
Bromoform,	2·900	Cahours.
Bronze,	8·482	Ure.*
Chinese,	8·815	"
Brookite,	4·125 to 4·169	Breithaupt.
transpt.,	4·128 to 4·131	H. Rose.
opaque,	4·165 to 4·167	"
Brown-spar,	3·404	Thomson.
Brucite,	2·350	Haidinger.
Bruennerite,	3·100	"
"	4·250	Mohs.
Bucholzite,	3·193	Thomson.
hydrous,	2·855	"
Bucklandite,	3·510	Hermann.
"	3·945	G. Rose.
Buntkupferenz,	5·003	Thomson.
Buratite,	3·200	Delesse.

Substances.	Density at 60° F.	Authority.
Burgundy-pitch,	1·080	Thomson.*
Burr-stone,	2·511	"
Bustamite,	3·12 to 3·25	"
Butter,	0·922	
Butyral,	0·821 at 71°	Chancel.
Butyric acid,	0·963	Pelouze.
"	0·967 at 77°	Thomson.*
Butyrone,	0·23 (?)	Chancel.
Bytowrite,	2·801	Thomson.
"	2·733	Hunt.
Cacoxenite,	2·336	Richardson.
Cadmium, oxide,	6·9302	Karsten.
"	8·183	W. Herapath.
carbonate,	4·420	"
"	4·494	Karsten.
sulphide,	4·605	Karsten.
"	4·900	Breithaupt.
Caffeine or Theine,	1·230	Thompson.*
Calamine or Zinc-spar,	3·584 to 3·598	Smithson.
"	4·334 to 4·376	Karsten.
"	4·442	Haidinger.
electric,	3·378	"
"	3·434	Smithson.
hydrous,	3·584	"
Calc-spar,	2·508	Haidinger.
(Iceland-spar),	2·524 to 2·723	Beudant.
"	2·721	Thomson.
"	2·735	Th. Herapath.
Calcium, fused, chl.,	2·240	Brisson.
Calculi, urinary,	1·463 to 1·741	Filhol.
biliary,	0·900 to 1·060	
salivary,	2·209 to 2·302	
Calomel, native,	6·482	
artif.,	7·176	Haidinger.

Substances.	Density at 60° F.	Authority.
Camphene,	0·860	Ure.
"	0 880	Thomson.
Camphor,	0·9857 to 0·997	Blanchet.
"	0·9887	Ure.*
"	0·9960	Shaw.
Cancrinite,	2·4530	
Candite,	3·6170	Gmelin.
Canzeranite,	2·690	Dufrénoy.
Caoutchine,	0·64	Brande.*
Caoutchouc,	0·919 to 0·9424	Ure.*
"	0·942	Th. Herapath.
Capnomor,	0·977	Reichenbach.
Capric acid,	0·91	Brande.
Caproic acid,	0·622	"
Carbolic acid,	1·062	"
Carbon, by decomp. of carb. acid,	1·571	Poselger.
" proto-chl.,	1·550	Brande.*
" chloro-sulp.,	1·460	Kolbe.
" bisulphide,	1·263	Cluzel.
" "	1·265	Couërbe.
" "	1·272	Berzelius.
" "	1·300	Lampadius.
Carbonic acid, liquid,	0·83 at 32° F.	Thilorier.
Cardol,	0·978	Stœdeler.
Carinthite,	5·706 to 6·760	Haidinger.
Carnelian,	2·59 to 2·62	
Castor,	2·38 to 2·40	Plattner.
Catapleite,	2·80	Weibye.
Cat's-eye, common,	2·600 to 2·625	Cresy.*
Catechu,	1·28 to 1·39	Ure.
Cedren,	0·98	Walter.
Celestine,	3 945 to 3 963	Thomson.
"	3·966 to 3·976	Th. Herapath.
Cerin,	0·969	John.

Substances.	Density at 60° F.	Authority.
Cerite,	4·500	Cresy.*
"	4·912	Haidinger.
Ceruse,	6·4 to 6·75	Brande.*
Ceylanite,	3·575	Thomson.*
"	3·765 to 3·793	Cresy.*
Chabasite,	2·088	Thomson.
"	2·100	Haidinger.
"	2·472	Lehunt.
"	2·717	Haüy.
Chalcedonite,	6·400	Brooke.
Chalcedony,	2·583 to 2·620	Hoffmann.
"	2·583 to 2·664	Brisson.
Chalk,	2·657	Moseley.
"	2·4 to 2·6	Ure.*
"	2·315	Tredgold.*
Chalk-stones,	1·5771	Th. Herapath.
Chalilite,	2·252	Thomson.*
Chamosite,	3·00 to 3·40	Berthier.
Charcoal, birch,	0·542	Kirwan.
fir,	0·441	"
oak,	0·332	"
pine,	0·280	"
Chiastolite,	2·04 to 3·09	Bunsen.
Chiolite,	2·72	Hermann.
Chloral,	1·502	Brande.*
mesitic,	1·330	Dumas.
Chloropal, earthy,	1·727 to 1·870	"
Chlorophæite,	2·020	McCulloch.
Chlorophane,	3·094	Haüy.
"	3·1400	Haidinger.
"	3·177	Th. Herapath.
Cholera, vomit,	1·012 to 1·0169	"
dejections,	1·016 to 1·0185	"
Chondrodite,	3·180	D'Ohsson.
"	3·199	Haidinger.

Substances.	Density at 60° F.	Authority.
Chondrodite,	3·157 to 3·228	Seybert.
Christianite,	2·201	Descloizeaux.
Chrome-iron,	4·321	Thomson.*
"	4·552	Th. Herapath.
Chromium, oxide of,	4·909 to 5·21	
sesqui-sulphide of,	4·092 at ·39°1	Playfair & Joule.
Chromic acid,	2·676	"
Chrysoberyl,	3·508 to 3·597	Seybert.
"	3·711 to 3·733	Thomson.
"	3·754	Haidinger.
Chrysolite, Brazilian,	2·692 to 3·340	Cresy.
Oriental,	3·410	Haidinger.
"	3·362	Stromeyer.
Chrysophrase,	2·608	Hoffmann.
"	3·250	Klaproth
Chrysotil,	2·219	Delesse.
Chyle,	1·0215 to 1·022	Marcet.
Cider,	0·9876	Ure.*
"	1·018	Moseley.*
" Devon,	1·0002	Th. Herapath.
Cimolete,	2·000	Cresy.
Cinnabar, native,	8·098	Thomson.
crystals,	10·218	Cresy.*
Cinnamene, or Styrole,	0·928	Kopp.
Cinnamic acid,	1·246	"
Cinnamole,	0·880	Marchand.
Citraconic acid,	1·247	"
Citric acid,	1·0345	Gray.*
"	1·617	Ure.*
Clausthalite,	7·187	H. Rose.
Clay, potters',	1·800 to 2·085	Kirwan.
common,	1·919	Belidor.
Clinker, English,	1·653	Tredgold.
Dutch,	1·482	"
Clink-stone,	2·575 to 2·620	Cresy.*

Substances.	Density at 60° F.	Authority.
Cluthalite,	2·166	Thomson.
Coke,	0·744	Kirwan.
Coal, Alleghany, Md. (Geo. Creek Co.),	1·3197	Morfit.
Anthracite, Pa. ("Black Diamond"),	1·4574	Morfit.
Anthracite, Pa. ("Balt. Co.")	1·5037	"
Coal, Bovey,	1·129	Vaux.
Caking,	1 269	Thomson.
"	1·274 to 1·280	Richardson.
cannel,	1·265	Thomson.
"	1·276	Vaux.
"	1·318 to 1·319	Richardson.
Kilkenny,	1·526	Kirwan.
Lykens Valley, Pa.,	1·5365	Morfit.
Newcastle,	1·264 to 1·288	Vaux.
Oregon,	1·578	"
Splint,	1·29	Thomson.
"	1·302 to 1·307	Richardson.
Coal-gas, charcoal,	1·800	Brande.*
Coal-naphtha,	0·82 to 0·86	"
Cobalt-glance,	6·298	Thomson.
ochre,	2·200	Breithaupt.
pt.-oxide,	5·597 to 5·75	Playfair and Joule.
peroxide,	4·814	"
"	5·322	W. Herapath.
proto-peroxide,	5·833	Brunner.
"	6·090	Berzelius.
"	6·296	Haüy.
pyrites,	5·450	Middleton.
radiated white,	6·5 to 7·131	Varrentrapp.
bisulphide,	4·269	Playfair and Joule.
sesqui-sulphide,	4·049	"
white ore of,	6·466	"
Cobaltic galena,	8·440	Du Menil.

Substances.	Density at 60° F.	Authority.
Cochineal,	1·250	Ure.*
Colophanite,	3·610	Richardson.
"	3·871 to 3·965	Thomson.*
Colophen,	0·940	Deville.
Columbite, America,	5·323	H. Rose.
Bodenmais,	5·704	"
Finland,	7·236 to 7·655	Berzelius.
Tamela,	7·264	Nördenskiold.
"	7·64 to 7·651	Damour.
"	7·963	Ekeberg.
Commingtonite,	3·2014	Thomson.*
Comptonite,	2·427	"
Condurrite,	4·20 to 4·29	Blyth.
"	5·2054	Phillips.
Coniine,	0·878	Blyth.
"	0·890	Geiger.
Copper, blue ore of,	3·831	Thomson.*
dark gray,	4·7 to 4·9	H. Rose.
glance,	5·702	Thomson.*
gray ore of,	4·798 to 5·104	Haidinger.
liver-colored ore of,	5·003	Thomson.*
mica,	2·548	Bournon.
native,	6·125	John.
"	7·6 to 7·8	Cresy.*
"	8·508	(?)
ruby ore,	5·8 to 6·0	Brande.*
prot.-oxide,	5·9 at 39°	Playfair and Joule.
"	6·13	Boullay.
"	6·40	Brande.
"	6·401	W. Herapath.
"	6·322	Filhol.
sub-oxide,	5·746	Playfair and Joule.
"	5·751	Karsten.
pyrites,	4·160	Thomson.*
schaum,	3·098	"

Substances.	Density at 60° F.	Authority.
Copper-salts, &c., acetate,	1·780	Gray.
chloride,	3·054	Playfair and Joule.
dichl.,	3·376	"
nitrate,	2·047	"
sub-nitrate,	2·765	"
sulphate crys,	2·242 to 2·2901	" and Filhol.
" anhyd.,	3·53	Filhol.
" sat. sol.,	1·15 at 42°	Cresy.*
sub-sulphate,	3·082	Playfair and Joule.
sulphide,	3·80	Wülchner.
sub-sulphide,	5·695	Mohs.
Copper ore, lenticular,	2·78	Thomson.
" "	2·882	Bournon.
" "	2·926	Haidinger.
Coprolites:—L. Regis,	2·644 to 2·700	Th. Herapath.
Coprolites, pseudo:—Suffolk,	2·7216 to 2·85	"
" powdered,	2·961	"
Coracite,	4·378	Le Conte.
Coral, white,	2·857	Moseley.*
" red,	2·570	"
Corundellite,	3·000	Silliman.
Corundum,	3·710	Moseley.*
Indian,	3·71 to 3·875	Cresy.*
Chinese,	3·981	"
Cotton,	1·470	?
Cotumnite,	1·897	Thomson.*
Cream,	1·0244	Berzelius.
Creasote, pure,	1·037	Reichenbach.
"	1·060	Christison.
Crocoisite,	6·100	Vauquelin.
Cronstedite,	3·348	Thomson.*
Crucite,	3·579 to 3·8095	"
Cryolite,	2·957	Cresy.*
"	2·949	Thomson.
Cryptolite,	4·600	Wöhler.

Substances.	Density at 60° F.	Authority.
Cumidine,	0·9526	Nicholson.
Cyanite,	3·517 to 3·622	Cresy.*
Cyanol,	1·028 at 68°	Hofman.
Cyanogen liq.,	0·900	Brande.*
Cymol,	0·857	Noad.
Cyprine,	3·2278	Richardson.
DATHOLITE,	2·99 to 3·346	
Davidsonite,	2·362	Thomson.*
Dechenite,	5·810	Bergmann.
Delvauxene,	1·850	Dumont.
Deweylite,	2·247	Thomson.
Dialogite,	3·592	Haidinger.
Diamond, Brazilian,	3·444 to 3·55	Moseley.
Oriental,	3·521 to 3·55	"
Diaspore,	3·4324	Haüy.
Diopside,	3·2374	Tonnellier.
Dipyre,	2·63 to 2·84	Cresy.*
Dolomite,	2·815 to 5·284	Thomson.*
"	2·71 to 2·85	R. D. Thomson.
Dragon's Blood,	1·196	Ure.*
" "	1·204	Moseley.*
Dreelite,	3·300	Dufresnoy.
Dysclasite,	2·280	L. Gmelin.
"	2·362	Thomson.*
Dysluite,	4·551	"
EARTH, common,	1·520 to 1·984	Tredgold.
loamy,	2·016	"
loose or sandy,	1·520	"
Earth (the earth, our planet),	4·715	Schehallier.
" "	4·750	Hutton.
" "	4·950	Carlini.
" "	5·448	Cavendish.
" "	5·507 to 5·847	Baily.

Substances.	Density at 60° F.	Authority.
Edwardsite,	4·2 to 4·6	Shepard.
Elacolite,	2·546 to 2·618	Hoffman.
Elæolite,	2·600 to 2·617	Scheerer.
Elathine,	1 —	Zeise.
Embolite,	5·806	Plattner.
Emerald,	2·58	Thomson.
"	2·732	Haidinger.
Brazilian,	3·15 ?	Cresy.*
Pseudo,	2·701	"
Emery,	4·000	Tennant.
"	3·74 to 4·31	L. Smith.
Ephesite,	3·15 to 3·20	"
Epidote,	3·425	Haidinger.
"	3·436 to 3·440	Thomson.
"	3·46	Descotils.
Epistilbite,	2·25	G. Rose.
Epsomite,	1·751	Thomson.
Erinite, of Thomson,	2·040	"
of Haidinger,	4·043	L. Gmelin.
Erlanite,	3·0 to 3·1	Gmelin.
Erythrite,	2·541	Thomson.
Esmarkite,	2·709	Erdmann.
Essonite, or Cinnamon-stone,	2·600	Cresy.*
"	3·631	Lehunt.
Euclase,	2·907	Lowry.
"	3·0625	Haüy.
"	3·098	Haidinger.
"	3·300	Moseley.*
Eudnophite,	2·270	Weibye.
Eudyalite,	2·9035	Stromeyer.
"	2·9036	Thomson.
Euphyllite,	2·9630	Silliman.
Eupion,	0·655	Thomson.
"	0·740	Brande.*
Euxenite,	4·600	Scheerer.

Substances.	Density at 60° F.	Authority.
FAHLUNITE,	2·620 to 2·790	Wachmeister.
Fatty acids,	1 —	
Fat or tallow,	0·936	Ure.*
Fayalite,	4·138	Gmelin.
Felsite,	2·545	Kerndt.
Felspar, potash,	2·395 to 2·574	H. Rose.
Fergusonite,	5·8 to 5·83	
Fibroferrite,	2·500	Prideaux.
Fibrolite,	3·214	Bournon.
Firestone,	1·800	Tredgold.*
Flax,	1·500	Ure.
Flesh,	0·923 to 0·934 (?)	Moseley.
Flint,	2·58 to 2·63	Thomson.
Formic acid, bihyd.,	1·1168	Ure.
monohyd.,	1·2353 at 53·5°	Liebig.
Fornacite,	2·85 to 3·11	Riensch.
Fousel oil,	0·812	Graham.
" "	0·8137	Otto.
Franklinite,	4·257	Thomson.*
"	4·870	Berthier.
Fuchsite,	2·860	Schaffheutl.
Fuller's-earth,	1·82 to 2·19	Ure.*
"	2·445 to 2·517	Thomson.*
Furfurol,	1·168	Fownes.
GABRONITE,	2·740	Ure.*
"	3·000	Thomson.*
Gadolinite,	4·028 to 4·030	Rinmann.
"	4·0497	Haüy.
"	4·223	Geiger.
"	4·23	Gmelin.
Gahnite,	4·238	Haidinger.
Galena,	7·536 to 7·652	Thomson.
Galligenstein,	2·036	Haidinger.
Garnet, common,	3·57 to 3·68	Cresy.*

Substances.	Density at 60° F.	Authority.
Garnet, common,	3·90 to 4·26	Thomson.*
" "	3·70	Moseley.*
brown,	2·829	Thomson.
black,	3·157 to 3·73	"
green,	3·372 to 3·640	Klaproth.
precious,	4·230	Moseley.*
"	4·208 to 4·357	Thomson.
"	4·085 to 4·352	Cresy.*
Gases and Vapors.†		
ACETIC ACID,	2·7700	Dumas.
" "	2·7565	T. H. cal.
Acetone,	2·019	Dumas.
"	1·9984	T. H. cal.
Acroleine,	1·897	Redtenbacher.
Æther, acetic,	3·067	Dumas.
"	3·0321	T. H. cal.
methylic,	1·617	Dumas.
"	1·5849	T. H. cal.
nitrous,	2·626	Dumas.
"	2·5842	T. H. cal.
Æthyl,	2·046	Frankland.
"	1·9995	T. H. cal.
oxide,	2·586	Dumas.
"	2·5497	T. H. cal.
bromide,	3·9750	Dumas.
"	3·6874	T. H. cal.
chloride,	2·2190	Thenard.
"	2·2396	T. H. cal.
iodide,	5·4750	Gay-Lussac.
"	5·3407	T. H. cal.
Alcarsin,	7·5550	Bunsen.
"	7·5803	T. H. cal.
Alcohol,	1·6130	Gay-Lussac.
"	1·5599	T. H. cal.

Substances.	Density at 60° F.	Authority.
Gases and Vapors.		
Aldehyde,	1·5320	Liebig.
"	1·5161	T. H. cal.
Ammonia,	0·5901	Davy.
"	0·5967	Biot and Arago.
"	0·5857	T. H. cal.
Ammonium, chloride,	0·8900	Bineau.
" "	0·9130	T. H. cal.
Amyl,	4·899	Frankland.
"	4·8955	T. H. cal.
oxide of,	5·490	Cahours.
"	5·378	T. H. cal.
Amylic alcohol,	3·147	Dumas.
	3·137	Apjohn.
	3·043	T. H. cal.
Antimony,	17·887	Gmelin, cal.
terchl.,	7·800	Marchand.
Arsenic,	10·600	Mitscherlich.
"	10·4747	T. H. cal.
terchl.,	6·3006	Dumas.
"	6·3399	T. H. cal.
teriodide,	16·100	Mitscherlich.
"	15·6432	T. H. cal.
Arsenious acid,	13·8500	Mitscherlich.
" "	13·7825	T. H. cal.
Arseniuretted hydrogen,	2·6950	Dumas.
" "	2·8254	T. H. cal.
BENZOIC ACID,	4·270	Dumas.
" "	4·2036	T. H. cal.
Boron,	0·7487	Gmelin, cal.
"	0·7580	T. H. cal.
fluoride,	2·3100	Dumas.
"	2·3709	J. Davy.
"	2·2208	T. H. cal.

† Atmospheric air, at 60° F. and 30 inches Bar. pressure, equal to 1.

Substances.	Density at 60° F.	Authority.
Gases and Vapors.		
Bromine,	5·540	Dumas.
"	5·3751	T. H. cal.
Bromoboracic gas,	8·6443	Poggiale.
" "	8·4643	cal.
Bromoform,	8·6300	Cahours.
"	8·7847	Thomson.
Butyric acid,	5·500	Pelouze.
Cacodyl,	7·101	Bunsen.
Camphene,	4·763	Dumas.
"	4·830	Cahours.
"	4·6860	T. H. cal.
Camphor,	5·468	Dumas.
"	5·2373	T. H. cal.
Caoutchine,	2·000	Dalton.
Capric acid,	5·980	(?)
Carbon,	0·4215	Graham, cal.
"	0·4160	Gmelin, cal.
"	0·41375	T. H. cal.
bromide,	2·436	Poselger.
"	2·3660	T. H. cal.
chloride,	5·820	Regnault.
"	5·7886	T. H. cal.
bisulphide,	2·6690	Mitscherlich.
"	2·6447	Gay-Lussac.
"	2·6880	Couerbe.
"	2·6124	T. H. cal.
Carbonic acid,	1·4994	Lavoisier.
" "	1·5191	Buff.
" "	1·5196	Biot and Arago.
" "	1·521	Lieb. & Redtenbach
" "	1·524	Allen and Pepys.
" "	1·5245	Berzelius & Dulong
" "	1·5926	Saussure.

Substances.	Density at 60° F.	Authority.
Gases and Vapors.		
Carbonic acid,	1·51607	T. H. cal.
oxide,	0·9400	Dalton.
"	0·9678	Cruickshanks.
"	0·9698	Thomson.
"	0·9727	Dulong & Berzelius.
"	0·96477	T. H. cal.
Carburetted hydrogen,	0·5590	H. Davy.
"	0·5513	T. H. cal.
Chloral,	5·1736	Thomson.
"	5·1339	T. H. cal.
Chlorine,	2·3400	Dalton.
"	2·395	H. Davy.
"	2·424	Gay-Lussac.
"	2·47	Thenard.
"	2·50	Thomson.
"	2·4808	T. H. cal.
oxide,	3·00	Gay-Lussac.
"	3·0321	T. H. cal.
peroxide,	2·360	H. Davy.
	2·3430	T. H. cal.
Chlorocarbonic acid gas,	3·4604	Thomson.
	3·6808	J. Davy.
"	3·4456	T. H. cal.
Chlorochromic acid,	5·900	Walter.
"	5·500	Dumas.
"	5·5117	Gmelin, cal.
Chlorocyanic or Phosgene gas,	2·1400	Dumas (?)
	2·1712	T. H. cal.
Chloroform,	4·1999	Dumas.
"	4·1998	T. H. cal.
Coal gas,	0·407 to 0·659	Dr. Ure.
Cyanogen,	1·8064	Gay-Lussac.
"	1·8190	Gmelin, cal.
"	1·7917	T. H. cal.

Substances.	Density at 60° F.	Authority.
Gases and Vapors.		
Fire-damp,	0·6 to 0·966	Turner.
Fluosilicic acid,	3·574	J. Davy.
"	3·600	Brande.*
"	3 5834	T. H. cal.
Fluorine,	1·292	Graham, cal.
"	1·3093	T. H. cal.
Hydriodic Acid,	4·3757	Thomson.
"	4·4429	Gay-Lussac.
"	4·3759	T. H. cal.
Hydrobromic acid,	1·9060	Bineau.
"	2·7220	T. H. cal.
Hydrochloric acid,	1·2300	Dalton.
"	1·2470	Biot and Arago.
"	1·2555	Buff.
"	1·2780	Gay-Lussac.
"	1·2748	T. H. cal.
Hydrocyanic acid,	0·9476	Dumas.
"	0·9303	T. H. cal.
Hydrofluoric acid,	0·6829	Gmelin, cal.
"	0·6819	T. H. cal.
Hydroselenic acid,	2·795	Bineau.
"	2·8425	T. H. cal.
Hydrosulphuric acid,	1·106	Kirwan.
"	1·1791	Thomson.
"	1·1912	Gay-Lussac.
"	1·1967	H. Davy.
"	1·236	Thenard.
"	1·1715	T. H. cal.
Hydrogen,	0·0688	Berzelius & Dulong
"	0·0693	Thomson.
"	0·0732	Biot and Arago.
"	0·0769	Lavoisier.
"	0·0920 (?)	Cavendish.

Substances.	Density at 60° F.	Authority.
Gases and Vapors.		
Hydrogen,	0·0692 to 0·0696	Dumas.
"	0·06891	T. H. cal.
Iodine,	8·7160	Dumas.
"	8·6829	T. H. cal.
Mercaptan,	2·326	Bunsen.
"	2·1363	T. H. cal.
Mercury,	6·9760	Dumas.
"	7·0300	Mitscherlich.
"	6·8912	T. H. cal.
bromide,	12·18	Mitscherlich.
"	12·2665	T. H. cal.
subchl. (calomel),	8·350	Mitscherlich.
"	8·1316	T. H. cal.
chlor. (cor. sublimate),	9·800	Mitscherlich.
"	9·372	T. H. cal.
iodide,	15·900	Mitscherlich.
"	15·6054	T. H. cal.
sulphide,	5·510	Mitscherlich.
"	5·4262	Gmelin, cal.
Methylene,	0·490	Dumas.
"	0·48238	T. H. cal.
Methylamine,	1·130	Würtz.
"	1·075	T. H. cal.
Methyl,	1·076	Kolbe & Frankland.
"	1·0336	T. H. cal.
oxide,	1·570	Regnault.
"	1·5849	T. H. cal.
Naphtha,	3·400	Pelletier.
"	3·390	Gmelin.
Naphthaline,	4·528	Dumas.
"	4·4104	T. H. cal.
Nicotine,	5·6300	Barruel.
"	5·6370	Barruel, cal.
Nitric oxide,	1·0388	Bérard.

Substances.	Density at 60° F.	Authority.
Gases and Vapors.		
Nitric oxide,	1·0416	Thomson.
"	1·0960	H. Davy.
"	1·1887	Kirwan.
"	1·0338	T. H. cal.
Nitrogen,	0·9426	Lavoisier.
"	0·9670	H. Davy.
"	0·9691	Biot and Arago.
"	0·972 to 0·9729	Dumas & Berzelius
"	0·985	Kirwan.
"	0·9647	T. H. cal.
Nitrous or Hyponitric acid,	1·720	Mitscherlich.
" "	1·5849	T. H. cal.
Nitrous oxide,	1·3629	Berthollet.
"	1·5204	Colin.
"	1·5269	Thomson.
"	1·6140	Dalton.
"	1·51607	T. H. cal.
Œnanthole,	4·0019	Bussy.
Oil-gas,	0·910 to 1·175	Ure.
Oil of turpentine,	4·830	Dumas.
	4·7633	T. H. cal.
Olefiant gas,	0·985	Saussure.
	0·9647	T. H. cal.
Oleine,	2·942	Fremy.
"	2·8943	T. H. cal.
Oxygen,	1·087	Fourcroy.
"	1·088	Allen and Pepys.
"	1·1026	Berzelius & Dulong
"	1·1030	Kirwan.
"	1·1031	Buff.
"	1·1036	Biot and Arago.
"	1·1056	Saussure.
"	1·1117	Thomson.
"	1·1280 at 32° (?)	Davy.

Substances.	Density at 60° F.	Authority.
Gases and Vapors.		
Phosphorus,	4·420	Dumas.
"	4·580	Mitscherlich.
"	4·4104	T. H. cal.
Phosphuretted hydrogen,	1·146	Rose.
" "	1·1214	Dumas.
" "	1·1650	Buff.
" "	1·2059	T. H. cal.
Pyroxylic spirit,	1·1200	Dumas.
" "	1·1210	Kane.
" "	1·1026	T. H. cal.
Selenious acid,	4·03	Mitscherlich.
" "	3·8591	T. H. cal.
Selenium,	16·5390	"
Silicon,	1·0261 (?)	Gmelin.
Sulphur,	6·5635	Dumas.
"	6·9000	Mitscherlich.
"	6·6156	T. H. cal.
chloride,	3·860	Dumas.
"	3·5835	T. H. cal.
Sulphuric acid,	3·000	Mitscherlich.
" "	2·762	Brande.*
" "	2·7576	T. H. cal.
Sulphurous acid,	2·193	H. Davy.
" "	2·2222	Thomson.
" "	2·2277	Buff.
" "	2·2340	Thénard.
" "	2·2470	Berzelius.
" "	2·2630	Kirwan.
Tellurium,	26·6227	Gmelin, cal.
"	26·4624	T. H. cal.
Tin,	4·0905	Gmelin, cal.
"	3·9960	T. H. cal.
Urethane,	3·1400	Dumas.
"	3·1300	Würtz.

Substances.	Density at 60° F.	Authority.
Gases and Vapors.		
Urethane,	3·0900	T. H. cal.
Urethylane,	2·620	Echevarria.
Valeric acid,	3·669	Graham.*
Water,	0·6240	Brande.*
"	0·6202	Graham.*
"	0·6202	T. H. cal.
Gastric juice,	1·005	Silliman.
Gaylussite,	1·928 to 1·95 (?)	Boussingault.
"	2·921	Barruel.
Gedrite,	3·260	Dufrésnoy.
Gehlanite,	2·91 to 3·02	Thomson.
Gelactine,	0·969	"
Geokronite,	5·88 to 6·43	Svanberg.
Gibbsite,	2·091	Thomson.
"	2·400	Torrey.
Gieseckite,	2·832	Haidinger.
Gilbertite,	2·648	Thomson.
Girasol,	4·000	Cresy.*
Gismondine,	2·180	Kobell.
Gjellebackite,	2·205	Thomson.
Glass, crown,	2·520	Moseley.*
Bohemian,	2·396	Gmelin.
bottle,	2·732	"
crystal,	2·9 to 3·25	"
flint,	3·00 to 3·103	Bontemps.
for optical purposes,	3·3 to 3·6	Guinard.
" "	3·60	Bontemps.
" "	3·77	Fraunhöfer.
green,	2·642	Moseley.*
mirror,	2·488 to 2·506	Gmelin.*
plate,	2·9420	"
"	2·7600	Tredgold.
"	2·249 to 2·408	Mayer and Brazier.

Substances.	Density at 60° F.	Authority.
Glauberite,	2·730	Brongniart.
"	2·897	Haidinger.
Glaucolite,	2·72 to 2·90	Bergmann.
Glauconite,	2·598 to 2·632	Thomson.*
Glottalite,	2·181	"
Glucina,	2·970	Brande.*
"	3·000	Turner.
Glycerine, concen. solu.,	1·252	Thomson.*
" "	1·270	Chevreul.
anhydrous,	1·280	Pelouze.
Gold-ore, Californian,	15·63 to 15·96	T. H. Henry.
Australian,	14·63	Thomas.
melted ditto,	18·83	"
Gorlandite,	6·410	Gregor.
Granitelle,	3·063	Cresy.*
"	2·846	"
Granite,	2·622 to 2·956	"
"	2·538 to 2·999	Kirwan.
"	2·5 to 2·6	Portlocke.
Graphite or Plumbago,	2·25 to 2·32	Thomson.
" "	2·140	Fuchs.
" "	2·273	Regnault.
" "	2·303	Th. Herapath.
Gravel,	1·749	Tredgold.
Greenockite,	4·80 to 4·908	Breithaupt.
Greenovite,	3·440	Dufrésnoy.
Greenstone,	2·7 to 3·0	Murchison.
Guanite,	1·65	Teschemacher.
Guano, African,	1·570	Ure.
Bolivian,	1·600	"
"	1·579	Th. Herapath.
Chincha I.,	1·600	Ure.
Colombian,	2·28	Morfit.
Peruvian,	1·700	Ure.
Saldanha B.,	1·799	Th. Herapath.

Substances.	Density at 60° F.	Authority.
Gum-Arabic,	1·3 to 1·5	Brande.*
"	1·355	Thomson.
"	1·4606 to 1·5256	Herberger.
Gum-Bassora,	1·359	Thomson.*
Gum, cherry-tree,	1·475 to 1·481	Moseley.*
mezqueet or mezgnite,	1·5	Morfit.
Senegal,	1·436	Guerin Barry.
"	1·586 to 1·654	Herberger.
tragacanth,	1·384	Thomson.
Gum-Resins:—		
Ammoniac,	1·207	Thomson.*
Asafœtida,	1·327	Brisson.
Bdellium,	1·371	"
Galbanum,	1·212	"
Gamboge,	1·207	Ure.*
"	1·221	Brisson.
"	1·222	Moseley.
Myrrh,	1·360	Brisson.
Opoponax,	1·622	"
Scammony,	1·235	"
Gunpowder,	1·836	Moseley.*
English,	1·800	Ure.
French,	1·793	"
Gunpowder including interstices.		
Pigeon & Wilkes's,	0·990	Ure.
French,	1·020	"
Battle,	1 030	"
Curtis & Harvey's,	1·050	"
Gymnite,	2·2165	Thomson.
Gurjan Balsam,	0·962	Lüdwig.
Guyaquillite,	1·092	Johnston.
Gypsum,	2·288	Moseley.*
"	2 310	Haidinger.
"	2·322	Roget and Dumas.

Substances.	Density at 60° F.	Authority.
Gypsum,	2·288 to 2·939	Cresy.*
HÆMATITE,	3·922	Haidinger.
red,	3·605	Yorke.
Hæmatite, ligniform,	3·443	Thomson.
Haidingerite,	2·848	Haidinger.
Harmotome,	2·40 to 2·448	Thomson.
Harringtonite,	2·217	"
Hartmannite,	6·450	H. Rose.
Hausmannite,	4·722	Turner.
Hauyne,	3·200	Cresy.*
soda,	2·470	Varrentrapp.
Hatchettine,	0·9657	T. Herapath.
"	0·983	Thomson.
Hedenbergite,	3·154	H. Rose.
Hedyphan,	5·460 to 5·493	Kersten.
Heliotrope,	2·700	Moseley.*
"	2·629 to 2·700	Cresy.*
Heloine,	3·166	Gmelin.
Herschellite,	2·110	Levy.
Hetopizite,	3·523	Dufrésnoy.
Heulandite,	2·200	Haidinger.
"	2·195	Thomson.
Heveëne,	0·921	"
Hone, white razor,	2·876 to 2·883	Cresy.*
Honey,	1·450	Moseley.*
Honey-stone or Mellite,	1·666	"
Hopeite,	2·760	Brewster.
Hornblende,	3·830	Moseley.*
common,	3·60 to 3·83	Cresy.*
"	3·00 to 3·50	L. Gmelin.
Horn-mangan,	3·1 to 3·5	Jashe.
"	3·89	Germac.
Hornstone,	2·81	Moseley.*
Humboldtite,	2·489	Thomson.

Substances.	Density at 60° F.	Authority.
Humboldtite,	2·89	Klaproth.
"	2·938	Haidinger.
"	2·900	Damour.
Huraulite,	2·270	Dufrésnoy.
Huronite,	2·865	Thomson.
Huttenbergite,	7·228	"
Hyalite,	2·400	Bucholz.
"	2·110	Cresy.*
Hyalosiderite,	2·875	Walchner.
Hydroboracite,	1·900	Hess.
Hydroborocalcite,	1·800	Ulex.
Hydromagnesite,	2·336	Brewster.
Hydrochloric acid,	1·270	Graham.*
concent. aqueous,	1·203	Thomson.
solution of,	1·210	Brande.*
of L. Ph.,	1·160	"
Hydriodic acid, liq.,	1 700	"
Hydrocyanic acid, anhyd.,	0·696	"
Hydrofluoric acid, anhyd.,	1·0609 (?)	"
hydrated,	1·25	"
Hydrolite,	2·054	Thomson.
Hydrosulphurous acid,	1·789	Thénard.
Hyperchloric acid, c. aq. solution,	1·704 to 1·811	Nativelli.
" "	1·600	Brandé.*
Hypersthene,	3·338	Muir.
"	3·355	Thomson.
Hyposist,	1·526	Cresy.*
Hyposulphuric acid, con. solu.,	1·347	Brande.*
Ice,	0·885	Meinke.
"	0·888 at 32°	Dulk.
"	0·905	Kraft.
"	0·920	Scoresby.
"	0·927	Osann.
Ice,	0·9184	Playfair and Joule.
"	0·937	Irving.
"	0·947	Williams.
"	0·950	Roger and Dumas.
Icespar,	2·436	Thomson.
Idocrase,	3·346	Varrentrapp.
"	3·349 to 3·399	Thomson.*
fused,	2·929 to 2·941	Magnus.
Ilmenic acid,	4·1 to 4·2	Hermann.
Ilmenite,	4·766 to 4·808	G. Rose.
Ilvaite,	3·9799	Stromeyer.
"	3·9940	Haidinger.
"	3·825 to 4·061	Lelievre.
Iodic acid,	4·250	Filhol.
Iodine,	4·948	Gay-Lussac and Thénard.
Indigo,	1·500	Ure.
Indigotine, sublimate,	1·350	W. Crum.
Inulin,	1·356	Parnell.
Iolite,	2·597	Stromeyer.
"	2·651 to 2·664	Thomson.
Iridium, native,	19·50	Wollaston.
" "	19·47 to 21·118	G. Rose.
Iron, apatite,	3·97	Fuchs.
arsenical,	6·13	Gmelin.*
hæmatitic,	3·555	Johnston.
magnetic, ore of,	5·092	Thomson.
"	4·9 to 5·2	Leonhard.
"	5·22 to 5·4	Boullay.
"	5·453	Playfair and Joule.
meteoric,	5·75 to 7·30	
phosphide,	6·70	Hatchett.
pyrites,	4·83 to 5·03	Thomson.
subsulphate of, native,	2·500	Prideaux.
subsulphide,	5·800	Playfair and Joule.

Substances.	Density at 60° F.	Authority.
Iron, sulphide,	5·026 to 5·046	Playfair and Joule.
sesqui-sulphide,	4·246	" "
bisulphide,	4·9 to 4·981	" "
sesqui-arsenide,	7·228	Reichenstein.
spathic, carbonate of,	3·737 to 3·829	
native,	5·95 to 6·72	Thomson.*
peroxide,	4·60 to 5·135	Playfair and Joule.
scale-oxide of,	5·480	Boullay.
Iron-ore, black-band,	3·0553	Colquhoun.
brown-clay,	4·3700	Yorke.
clay,	3·1175 to 3·3801	Colquhoun.
manganesian,	5·076	Thomson.
needle,	4·320	Breithaupt.
pitchy,	3·459	Vauquelin.
"	3·562	Breithaupt.
specular,	4·491 to 5·059	Kirwan.
"	5·251	Haidinger.
"	5·2998	T. Herapath.
yellow,	2·78 to 2·90	Rammelsberg.
Iron, salts of:—acetate,	1·368	Gray.*
chloride, crys.,	1·926	Filhol.
phosphate,	2·600	Gray.*
sulphate, dry,	2·640	Brande.*
"	2·841	Filhol.*
" crys.,	1·800	Brande.*
"	1·889 at 39°	Playfair and Joule.
"	1·904	Filhol.
sat. solu.,	1·15 at 52°	Cresy.*
Iserine,	4·491	Thomson.
"	4·5 to 4·65	Klaproth.
Isinglass,	1·1110	Moseley.*
" dry,	1·2097	T. Herapath.
Ittnerite,	2·3854	Thomson.*
Ivory,	1·825 to 1·899	Moseley.*
" vegetable,	1·376	A. Connel.

Substances.	Density at 60° F.	Authority.
JADE,	2·801 to 2·9829	
oriental,	2·970	Damour.
Jamesonite,	5·564	Thomson.*
"	5·616	Schaffgotsche.
Jasper,	2·62 to 2·816	Cresy.*
Jenite,	3·8 to 4·0	"
Jeffersonite,	3·510	Keating.
Jet,	1·259	Cresy.*
"	1·300	Moseley.*
Johannite,	3·190	Phillips.
Junkerite,	3·815	Dufrénoy.
Juice of apples,	1·060 to 1·084	Couverchel.
Juice, cane,	1·046 to 1·110	Evans.
"	1·033 to 1·106	Porter.
of average quality,	1·07 to 1·09	
KAMMERERITE,	2·640	Nordenskiold.
Kaolin, or porcelain clay,	2·216	Karsten.
" "	2·484	Thomson.
" "	2·47 to 2·64	Laurent.
Kapnite,	4·00 to 4·15	Manheim.
Karpholite,	3·923 to 3·936	
Karphosiderite,	2·500	Breithaupt.
Karsten,	2·652 to 2·668	Köhler.
Kilbrickenite,	6·407	Apjohn.
Killinite,	2·711	Taylor.
Kirwanite,	2·941	Thomson.
Knebelite,	3·714	Döbereiner.
Kobellite,	6·29 to 6·32	Setterberg.
Konichalcite,	4·123	Breithaupt.
Krokydolite,	3·200	Stromeyer.
Kupaphrite,	3·098	Thomson.
LABRADORITE,	2·690	Klaproth.
"	2·695 to 2·7025	G. Rose.

Substances.	Density at 60° F.	Authority.
Labradorite,	2·699	Thomson.
Lactic acid,	1·215	Thomson.
Lamarkite,	6·8 to 7·0	Brooke.
Lard,	0·947	Moseley.*
Latrobite,	2·800	Brooke.
Lazulite,	3·057	Fuchs.
"	3·106 to 3·123	Rammelsberg.
Laumonite,	2·200	Cresy.*
Laurel-turpentine,	0·8645	Stenhouse.
Lead, acetate, anhydrous,	2·570	Gray.*
crystallised,	2·345	"
arseniate, native,	6·410	Gregor.
bitelluride,	7·085	Thomson.*
carbonate of, native,	6·465 to 6·480	"
carbonate of, artifi.,	6·40 to 6·75	Brande.*
cupreo-sulphate of,	5·30	Brooke.
chloride,	5·823	Karsten.
" fused,	5·680	"
chromate,	5·653	Playfair and Joule.
dichromate,	6·266	" "
sesqui-chromate,	5·750	" "
iodide of,	6·028 to 6·111	Boullay.
"	6·394	Filhol.
nitrate of,	4·316 to 4·472	Playfair and Joule.
"	4·581	Filhol.
sub-nitrate of,	5·645	Playfair and Joule.
protoxide,	9·250	" "
"	9·277	W. Herapath.
"	9·209	Karsten.
"	9·361	Filhol.
"	9·4214	Graham.*
peroxide of,	8·756 to 8·897	Playfair and Joule.
"	8·900	W. Herapath.
"	9·190	Boullay.
suboxide of,	9·772	Playfair and Joule.

Substances.	Density at 60° F.	Authority.
Lead, selenide of,	7·187	H. Rose.
sulphate of,	6·300	Filhol.
sulphato-carbon. of,	6·8 to 7·0	Brooke.
sulphide of,	6·9328	Playfair and Joule.
" nat.,	7·500	Karsten.
"	7·568	Mohs.
"	7·587	Brisson.
"	7·2200	Muschenbroack.
"	7·4 to 7·6	Leonhard.
tungstate,	8·000	Breithaupt.
vanadiate,	6·663	Thomson.
Leadhillite,	6·3 to 6·5	Brooke.
Lead-ore, corneous,	6·056	Chenevix.
heavy,	9·392 to 9·448	Breithaupt.
white,	6·465 to 6·480	Thomson.
yellow,	5·706	Hatchett.
"	6·760	Haidinger.
red,	6·000	Thomson.
Lederitite,	2·169	Jackson.
Leelite,	2·606	Clarke.
Lehuntite,	1·953	Thomson.
Lenzinite,	1·8 to 2·1	John.
Lepidolite,	2·816 to 2·854	Cresy.*
Lepidomelane,	3·000	Soltmann.
Leucite,	2·490	Thomson.
Leucol,	1·081	Hofmann.
Leucophane,	2·974	Herrman.
Leucopyrite,	6·127	Thomson.
Levyne,	2·198	Connell.
Liebethenite,	3·6 to 3·8	Thomson.
Liebenerite,	2·814	Marignac.
Liebigite,		
Ligurite,	3·490	Viviani.
Lime,	2·3 (?)	Brande.*
"	3·08	Dumas.

Substances.	Density at 60° F.	Authority.
Lime,	3·16	Karsten.
"	3·18	Filhol.
hydrate,	2·078	"
acetate,	1·005 (?)	Gray.*
baryto-fluate,	3·750	Smithson.
nitrate, anhyd.,	2·2700	Filhol.
nitrate, crys.,	1·620	Gray.
"	1·780	Filhol.
oxalate,	1·833	Brooke.
bone-phosphate,	3·000	Gray.
tungstate,	5·959	Thomson.
"	6·076	Haidinger.
Limestone,	3·000	Moseley.
compact,	1·8364 to 2·720	Cresy.*
green,	3·182	"
arenaceous,	2·742	"
Linarite,	5·3 to 5·4	Phillips.
Lithomarge,	2·457	Thomson.
Lobeline,	0·950	
Lomonite,	2·300	Haüy.
Lonchidite,	4·925 to 5·001	Breithaupt.
Lymph,	1·037	Marchand and Col-berg.
"	1·017	Geiger.
MAGNESIA,	3·070	Richter.
"	3·200	Karsten.
acetate of,	1·378	Gray.*
borate of,	2·566	"
carbonate of,	2·612	Moseley.*
ferro-carbonate of,	3·001 to 3·112	Thomson.*
nitrate of,	1·460	Gray.*
phosphate of,	1·550	"
racemate of,	1·980	Thomson.
sulphate of,	1·683	Playfair and Joule.
"	1·751	Filhol.

Substances.	Density at 60° F.	Authority.
Magnesia, sulphate of, anhyd.,	2·628	Filhol.
"	2·606	Karsten.
c. solu.,	1·232	Cresy.*
sulphite of,	1·380	Gray.*
tartrate of,	1·960	Thomson.
Magnesite or Baudisserite,	2·200	Cresy.
" "	2·808	Breithaupt.
" "	2·915	Klaproth.
" "	2·950	Stromeyer.
Magnesium,	1·562	Playfair and Joule.
chloride of,	1·558	Filhol.
"	1·600	Gray.*
Malachite,	3·994	Moseley.*
"	4·008	Haidinger.
Mangan-blende,	3·95 to 4·014	Thomson.
Manganese, diarsenide,	5·550	Kane.
protoxide,	5·380 at 39·1°	Playfair and Joule.
sesquioxide,	4·568 to 4·619	" "
"	4·820	Leonhard.
peroxide,	4·8 to 4·9	Brande.*
red-oxide,	4·325	Playfair and Joule.
racemate,	1·960	Thomson.
sulphate,	2·877	Gray.*
Manganese-glance,	3·95 to 4·01	Leonhard.
" "	4·014	Mohs.
Manganese ore, gray,	3·819	Thomson.*
" "	4·917	
Manganiferous zinc-spar,	3·98 to 4·20	Monheim.
Manganite,	4·312 to 4·328	Turner.
Marble,	2·700	Ure.*
"	2·690 to 2·727	
Margarite,	3·0 to 3·1	Dumenil.
Marl,	1·6 to 2·87	Thomson.*
"	2·9444	Cresy.*
Meconium,	1·148	Davy.

Substances.	Density at 60° F.	Authority.
Meerschaum,	2·6 to 3·4	Ure.*
Meionite,	3·100	Cresy.*
"	2·612 to 2·650	Thomson.*
Melam,	1·640	Prout.
Melanchlore,	3·380	Fuchs.
Melanite,	3·157 to 3·730	Thomson.
"	3·800	Moseley.*
Melanchroite,	5·750	Thomson.*
Melilite,	2·950	Damours.
Mellite,	1·55 to 1·597	Klaproth.
Menachanite,	4·427	Thomson.
"	3·160 (?)	Cresy.*
Mendipite,	7·000 to 7·077	Berzelius.
Mercaptan,	0 837	Liebig.
"	0·842	Zeise.
seleniuretted,	+ 1	Siemens.
Mercury, native,	13·568	Thomson.
proto-chloride,	7·178 at 39·1°	Playfair and Joule.
"	7·176	Hasenfratz.
perchloride,	6·200	"
"	6·500	Graham.*
potassio-chloride,	3·735	Playfair and Joule.
sodio-chloride,	3·011	" "
biniodide,	6·250	Filhol.
protoxide,	10·690	W. Herapath.
peroxide,	11·000	Boullay.
"	11·074	Berzelius.
"	11·085	W. Herapath.
"	11·196	Karsten.
"	11·344	Playfair and Joule.
red oxide,	11·136	" "
proto-nitrate,	4·785	" "
per-nitrate,	5·967	" "
basic nitrate,	4·242	" "
sub-sulphate,	6·444	Gray.*
Mercury, sub-sulphate,	8·319	Playfair and Joule.
Mesite,	0·805	Reichenbach.
Mesitine-spar,	3·360	Stromeyer.
Mesolite,	2·218 to 2·225	Thomson.
"	2·333	Freysmuth.
Methylene,	0·800	Thomson.
Methylic ether, acetic,	0·919 at 70·5°	Dumas and Peligot.
benzoic,	1·100	" "
nitric,	1·182 at 71°	" "
sulphuric,	1·324	" "
valeric,	0·8806	Löwig.
Methyl, bromide of,	1·663 at 55·5°	Pierre.
fluoride,	1·186	Dumas and Peligot.
iodide,	2 237 at 71°	" "
sulphide,	0·845	" "
bisulphide,	1·046	Cahours.
Methylic-mercaptan,	— 1	"
Metals:—Aluminium,	2·5 to 2·67	Wöhler.
Antimony,	6·610	Breithaupt.
"	6·646	Mohs.
"	6·700	Karsten.
"	6·712	Brisson.
"	6·733	Boeckmann.
"	6 852	Muschenbroeck.
"	6·860	Bergmann.
Arsenic,	5·628	Karsten.
"	5·672	W. Herapath.
"	5·7 to 5·96	Guibourt.
"	5·763	Brisson.
"	5·766	Mohs.
"	5·884	Turner.
Barium,	4·000	Davy.
Bismuth,	9·650	Karsten.
"	9·670	Muschenbroeck.
"	9·800	Brisson.

Substances.	Density at 60° F.	Authority.
Metals—*continued.*		
Bismuth,	9·832	W. Herapath.
"	9·882	Thénard.
Cadmium,	8·604	Stromeyer.
"	8·635	Karsten.
"	8·659	W. Herapath.
"	8·670	Children.
Chromium,	5·100	Thomson.
"	5·900	Richter.
Cobalt,	8·485	Brunner.
"	8·500	Mitscherlich.
"	8·513	Berzelius.
"	8·538	Haüy.
"	8·558	T. H. Henry.
Columbium or Tantalium,	5·600	Moseley.*
" "	5·918 to 6·208	Cresy.*
Copper,	8·721	Karsten.
"	8·830	Berzelius.
"	8·884 to 8·941	Playfair and Joule.
"	8·895	Hatchett.
"	8·900	W. Herapath.
Gold,	19·299	G. Rose.
	19·258 to 19·361	Brisson.
standard; coin,	17·158	Brande.*
" "	17·157	Cresy.*
" "	17·724 (?)	Thomson.
" trinkets,	15·709 to 15·775	Cresy.*
Iridium,	18·680	Children.
"	19·500	Mohs.
"	21·78 to 21·83	Hare.
"	22·11 to 23·55	Breithaupt.
Iron:—Cast,	7·264	Templeton.
	7·2 to 7·6	Thomson.
bar,	7·700	Templeton.
"	7·6 to 7·8	Kirwan.

Substances.	Density at 60° F.	Authority.
Metals—*continued.*		
Iron:—Bar,	7·788	Brisson.
"	7·790	Karsten.
Lead,	11·2070	Broeckmann.
"	11·3520	W. Herapath.
"	11·275 to 11·298	Playfair and Joule.
"	11·330	Kupffer.
"	11·3888	Morveau.
"	11·445	Muschenbrooch.
Magnesium,	2·23 to 2·25	Playfair and Joule.
Manganese,	6·861 to 7·100	Bergmann.
	8·030	Backmann.
	8 013	John.
Mercury,	13·588	Kupffer.
"	13·619 at 32°	Cresy.*
"	13·580 at 60°	"
"	13·375 at 212°	Cresy.*
frozen,	14·000	Kupffer and Cavallo.
Molybdenum,	7·500	Hielm.
"	8·6156 to 8·636	Bucholz.
Nickel,	8·279	Richter.
"	8·380	Tupputi.
"	8·402	Tourte.
"	8·477	Baumgartner.
"	8·637	Brunner.
Osmium,	10·000	Playfair and Joule.
Palladium,	10·923	Breithaupt.
"	11·800	Moseley.*
Platinum,	19·500	Templeton.*
"	19·700	Hare.
"	20·970	Brisson.
bar,	21·230 to 21·310	Hare.
"	23·500	Claus.

Substances.	Density at 60° F.	Authority.
Metals—*continued.*		
Potassium,	0·865	Gay-Lussac and Thenard.
Rhodium,	11·000	Wollaston.
	11·200	Claus.
Ruthenium,	8·60	"
Silver,	10·474	Brisson.
bar,	10·566	G. Rose.
"	10·522	Playfair and Joule.
standard coin,	10·300	Brande.*
	10·312	Thomson.*
Sodium,	0·972	Gay-Lussac and Thenard.
"	0·935	Davy.
Strontium,	4·0 to 5·0	Gehler.
Tellurium,	6·115	Klaproth.
"	6·13 to 6·258	Berzelius.
"	6·343	Müller.
Tin,	7·17 to 7·291	Cresy.*
"	7·248	Playfair and Joule.
"	7·285	W. Herapath.
"	7·291	Brisson, &c.
Titanium,	5·280	Karsten.
"	5·300	Wollaston.
Tungsten,	17·220	Allen and Aiken.
"	17·400	Bucholz.
"	17·600	D'Elhuyart.
Uranium,	8·425	Playfair and Joule.
Zinc,	6·861	Brisson.
"	6·862	Berzelius.
"	6·843	Playfair and Joule.
bar,	7·190	Brisson.
Methylal,	0·855	Graham.*
Mesiten,	0·808	Weidemann.

Substances.	Density at 60° F.	Authority.
Miargyrite,	5·234	H. Rose.
Mica,	2·824	Thomson.
"	2·934	Moseley.*
"	2·949	Haidinger.
"	3·080	Turner.
"	3·127	Delesse.
Microcosmic salt,	1·500	Gray.*
Middletonite,	1·600	Johnston.
Milk, asses',	1·030 to 1·035	Peligot.
cows',	1·0324	Brisson.
" (*average quality*),	1·0330 to 1·064	Lassaigne.
ewes',	1·035 to 1·041	Brisson.
goats',	1·0341	"
mares',	1·0346 to 1·045	"
womens',	1·023	"
	1·028 to 1·034	Griffith.
Molybdenum, sulphide,	4·138 to 4·569	Graham.*
" "	4·7385	Brisson.
Molybdic acid,	3·460	Thomson.
" "	3·490	Berzelius.
oxide,	5·666	Bucholz.
Monazite,	4·880 to 4·992	Breithaupt.
Monradite,	3·267	Erdmann.
Mosandrite,	2·93 to 2·98	"
Mountain leather,	1·334	Thomson.
Moringic acid,	0·908	Walter.
Mortar,	1·384 to 1·993	Rondelet.
Mucamide,	1·589	Malaguti.
Mucic acid,	+ 1	
Mullicite,	1·787	Thomson.*
Murchisonite,	2·509	Kane.
Muromontite,	4·263 to 4·265	Kerndt.
Must of grapes,	1·065 to 1·085	Crasso.
Myrrh,	1·12 to 1·18	Ruickholdt.
Mysorite,	2·620	Thomson.

Substances.	Density at 60° F.	Authority.
NACRITE,	2·788 to 2·793	Thomson,
Naphtha, coal,	0·9 to 0·95	Mansfield.
rectified coal,	0·82 to 0·86	Brande.*
"	0·817	Reichenbach.
"	0·857	Ure.
Persian,	0·753	Christison.
"	0·765	Gregory.
Naphthaline,	1·048	Ure.*
Natrolite,	2·723	Ekeberg.
"	2·139 to 2·2303	Thomson.
Nemalite,	2·353	"
	2·440	Nuttall
Néoctèse,	3·180	Damour.
Nepheline,	2·560	Scheerer.
"	3·270	Roget and Dumas.
Nephrite,	2·595	Thomson.*
Neurolite,	2·476	"
Newkirkite,	3·824	Muir.
Nickel, antimonial,	7·541	Breithaupt.
diarsenide,	7·655	Thomson.*
carbonate,	2·570 to 2·693	Silliman.
oxide,	5·597 at 39·1°	Playfair and Joule.
"	5·748	Genth.
peroxide,	4·814	Playfair and Joule.
"	4·846	W. Herapath.
sulphate,	2·037	Kopp.
sulphide,	5·278	Playfair and Joule.
disulphide,	6·050	" "
sulph-antimonide,	6·097	G. Rose.
Nickel-glance,	6·129	Thomson.
Nicotine,	1·048	H. & B. Chalard.
"	1·033 at 39°	Barral.
"	1·027 at 60°	"
"	0·9424 at 215°	"
Nigrine,	4·445	Klaproth.

Substances.	Density at 60° F.	Authority.
Nigrine,	3·700 to 4·673	Cresy.*
Niobic acid, amorph.,	5·2545 to 5·2620	Rose.
crys.,	4·664 to 4·7633	"
Nitranisole,	+ 1	Cahours.
Nitre,	1·933	Thomson.*
Nitric acid, red and fuming, or monohydrate,	1·500 to 1·522	A. Smith.
" bihyd.,	1·485	Ure.
" "	1·486	A. Smith.
" 4-hyd.,	1·424	"
" 7-hyd.,	1·335	Ure.
Nitrous, or hyponitric acid,	1·451 at 0°	Graham.*
Nitrogen, iodide of	+ 1	
" 4-chloride of,	1·653	Dulong. (?)
Nussierite,	5·0415	Barruel.
OBSIDIAN,	2·370	Moseley.*
"	2·363 to 2·373	Thomson.*
Oerstedite,	3·629	Forschammer.
Œnanthole,	0·8271	Bussy.
Oils—almonds, fixed,	0·915	Saussure.
" "	0·918	Ure,* &c.
" "	0·932 (?)	Moseley.*
" vol.,	1·043 (?)	Graham.*
Anise,	0·986	Saussure.
Bergamot,	0·862	Ohme.
"	0·869	Soubeiran.
"	0·888	Thomson.*
Castor,	0·9611	Reichenbach.
"	0·9650	Saussure.
Cinnamon,	1·035	Ure,* &c.
"	1·043	Moseley.*
Cloves of commerce,	1·034	Lewis.
pure,	1·055 to 1·061	Bonastre.
Cocoa-nuts,	0·910	Brande.*

Substances.	Density at 60° F.	Authority.
Oils—*continued.*		
Cod-livers,	0·923 to 0·929	Moseley.*
Colza,	0·9136	Thomson.*
"	0·91413	Alexand'r & Morfit
"	0·91049	"
"	0·91408	"
Lard of 16° F.	0·91546	"
Lavender,	0·877 to 0·905	Thomson.*
"	0·894	Moseley.*
Lemons,	0·847	Saussure.
Linseed,	0·928 to 0·932	Brande.*
	0·9347	Ure.*
Nut-oil,	0·926	"
Olives,	0·9176	Heidenbacher.
"	0·917	Saussure.
Peppermint,	0·920	Thomson.
	0·907 to 0·9083	Kane.
Rape,	0·9128 to 0·9167	Thomson.*
	0·9136	Heidenreisch.
Rosemary,	0·889	Berzelius.
	0.8854 to 0·8875	Kane. Saussure.
Roses,	0·867 to 0·872	Chardin.
Rosin,	0·97182	Alexand'r & Morfit
Seal,	0·92489	"
Sperm of 34° F. (winter),	0·87971	"
" 40° F. (summer).	0·88056	"
Turpentine,	0·87 to ·872	Brande.*
" pure,	0·863	Pereira.
" com.	0·87 to 0·884	"
Whale, or train oil,	0·923	Heidenreisch.
" of 10° F.	0·92000	Alexand'r & Morfit
Okenite,	2 280	Von Kobell.
Oleic acid,	0·898 at 65°	Brande.
Oleine,	0·9003	Heidenreisch.
Oligoclase,	2·6680	Berzelius.

Substances.	Density at 60° F.	Authority.
Oligoclase,	2·66 to 2 68	Kerudt.
Olivine,	3·286 to 3·3445	Stromeyer.
" meteoric,	3·3404 to 3·3497	"
Olivenite,	4·166	Richardson.
"	4·2809	Bournon.
"	4·2 to 4·6	Phillips.
Opal, precious,	2·015 to 2·210	Klaproth.
" "	2·114	Moseley.*
" common,	1·957 to 2·114	"
" ligniform,	2·600	Cresy.*
" semi,	2·540	"
Opium,	1·336	Moseley.*
Orthite,	3·288	Thomson.*
"	3·4 to 3·6	Hermann.
Orthose,	2·615	Saussure.
Osmio-iridium,	19·835	Boyé.
"	19·385 to 19·471	G. Rose.
"	20·938	Hare.
"	21·118	Rose.
Oxalhydric acid,	1·418 at 68°	Thomson.*
Oxalate of iron,	2·489	Thomson.*
Oxalic acid,	1·6413 at 39·1°	Playfair & Joule.
"	1·62	Gray.*
Oxygenated water,	1·45	Brande.*
Oyster shells,	2·092	Moseley.*
Ozocerite,	0·885	Johnston.
PALLADIUM, native,	11·800	Wollaston.
	12·140	Lowry.
Paraffine,	0·870	Graham.*
"	0·890	Lewy.
Parasite,	4·35	Spada.
Paulite,	3·385	Klaproth.
Pearls, Oriental,	2·683	Brewster.
"	2·750	Moseley.*
Pearl-stone,	2·340	Cresy.*

Substances.	Density at 60° F.	Authority.
Peat,	0·8495	Vaux.
" hard,	1·3290	Tredgold.
Pebble, English,	2·609	Tredgold.
Pektolite,	2·690	Von Kobell.
Pelokonite,	2·567	Richter.
Pelopic acid,	5·98 to 6·735	Rose.
Pennine,	2·653 to 2·659	Marignac & Descloiz.
Pentathionic acid, con. solu.,	1·67	Fordos and Gelis.
Perchloric,	1·600	Brande.*
" acid,	1·717 to 1·800	Nativelli.
Periclase,	3·750	Scacchi.
Pericline,	2·640	Abich.
Perowskite,	4·071	G. Rose.
Peristerite,	2·568	Thomson.
Perthite,	2·586	"
"	2·576 to 2·579	Hunt.
Petalite,	2·420	Arfwedson.
"	2·426	Gmelin.
"	2·450	Dr. Clarke.
Petrolene,	0·891 at 70°	Boussingault.
Pharmacolite,	2·536	Selb.
	2·640	Klaproth.
	2·730	Haidinger.
Pharmacosiderite,	3·000	Bournon.
Phenamylole,	—1	Cahours.
Phenakite,	2·969	Nordenskiöld.
Phocenic acid,	0·937 at 77°	Brande.*
Pholerite,	2·564	Smith.
Phloridzine,	1·4298	Graham.*
Phosphocerite,	4·780	Watts.
Phosphoric acid.		
" vitreous,	2·387	Brisson.
" hydrated,	2·000	Brande.*
" acid of L. Ph.,	1·064 at 62°	Brande.*
Phosphorus,	1·770	Berzelius.
Phosphorus,	1·869	Böckmann.
"	2·033	Fourcroy.
"	2·089 at 63°	Böttger.
solid.,	1·83 at 50°	Schröetter.
liq.,	1·88 at 113°	"
amorp.,	1·964	"
terchloride,	1·45	Davy.
persulphide,	2·02	Dupré.
oxychloride,	1·700 at 54°	Würtz.
Picamar,	1·100 at 68°	Reichenbach.
Picrolichenite,	1·176	Alms.
Picrolite,	2·591	Thomson.*
Picrosmine,	2·596 to 2·660	"
"	2·976	(?)
Pichuric acid,	0·883 at 68°	Georgey.
Pickeringite,	1·78 to 1·80	Hayes.
Pikrophyll,	2·730	Svanberg.
Pinite,	2·782	Haidinger.
"	2·757	Gmelin.
Pinguite,	2·315	Breithaupt.
Pipestone,	2·607	Thomson.
Pistacite,	3·390 to 3·490	Herrmann.
Pitch-blende,	6·468	Thomson.*
Pitch-stone,	2·338 to 2·3604	"
Pitch,	1·08	"
"	1·150	Tredgold.
Pittizite,	2·400	Karsten.
Placodine,	7·988 to 8·062	Plattner.
Plagionite,	5·400	Thomson.*
Planets:—Saturn,	0·2461	Author of the Vestiges of the N. H. of the Creation.*
Jupiter,	1·047	
Mars,	3·2870	
Earth,	4·50 (?)	
Venus,	5·7333	
Mercury,	9·9000	

Substances.	Density at 60° F.	Authority.
Plenakite,	3·086	Bischoff.
Plaster, cast,	1·286	Belidor.
Platinum, native,	16·000 to 18·940	Humboldt.
bisulphide,	7·224	Böttger.
protosulphide,	6·20 (?)	Brande.*
sulphide,	8·840	Böttger.
Pleisto-magnetic iron,	5·094	Berzelius.
Plinthite,	2·342	Thomson.
Plomb-gomme,	4·880	Dufresnoy.
Plumbo-calcite,	2·824	Johnston.
Polyadelphite,	3·767	Thomson.
Polybasite,	6·214	G. Rose.
Polyhallite,	2·770	Stromeyer.
Polylite,	3·231	Thomson.
Polymignite,	4·806	Berzelius.
Polysphærite,	6·092	Breithaupt.
"	6·029 to 6·983	Karsten.
Poonahlite,	2·262	Gmelin.
Porcelain, China,	2·384	Moseley.*
Sèvres,	2·148	"
Porcelainite,	2·300	Cresy.*
Porphyry,	2·676 to 2 972	Moseley, &c.*
"	2·4 to 2·6	Portlocke.
Potassa, anhyd.,	2·656	Karsten.
hyd.,	2·044	Filhol.
Potassa-fusa,	1·706 (?)	Ure, &c.*
Potassa, carbonate, anhyd.,	2·2643	Karsten.
"	2·267	Filhol.
fused,	2·600 (?)	Brande.*
sat.,	1·500	"
sol.,	1·540	Dalton.
bicarbonate,	2·053 at 39·1°	Playfair and Joule.
"	2·085	Gray.*
chlorate,	1·989	Brande.*
"	2·3264 at 39·1°	Playfair and Joule.
Potassa, chromate,	2·600	Gray.*
"	2·711 at 39·1°	Playfair and Joule.
"	to 2 723	
bichromate,	2·620	Gray.*
"	2 692 at 39·1°	Playfair and Joule.
sesquichromate,	2·624	" "
terchromate,	2·655	" "
ferrocyanate,	1·830	Gray.*
nitrate,	1·933 to 2·073	"
"	2·0985 to 2·1078	Playfair and Joule.
oxalate,	2·1265	" "
binoxalate,	2·044	" "
4-oxalate,	1·8488	" "
biphosphate,	2·850	Gray.*
racemate,	2·080	Thomson.*
biracemate,	2·558	"
sulphate,	2·623	Karsten.
"	2·636	Watson.
"	2·656	Playfair and Joule.
anhyd.,	2·625	Filhol.
sat., solu.,	1·972 at 470°	Anthon.
"	1·0798 at 66°	Karsten.
bisulphate,	2·277	Jacquelain.
"	2·478	Playfair and Joule.
sulphite,	1·586	Gray.*
tartrate,	1·556	"
"	2·140	Thomson.
soda-tartrate,	1·740	Mitscherlich.
bitartrate,	1·950	Gray.*
Potassæ, liquor, L. Ph.,	1·063	Brande.*
Potassium, chloride crystal,	1·910 at 391·1°	Playfair and Joule.
anhyd.,	1·984	Filhol.
"	1·945	Kopp.
"	1·977	Playfair and Joule.

Substances.	Density at 60° F.	Authority.
Potassium, chloride, anhyd.,	1·915	Karsten.
sat.,	1·1635 at 64°	"
solu.,		"
bromide,	2·415	Playfair and Joule.
"	2·675	Karsten.
iodide,	2·9084	"
"	3·056	Boullay.
"	3·091	Filhol.
sulphide,	2·130	Brande.
Potato-starch,	1·500	Kirwan.
Pot-stone,	2·768 to 3·000	Cresy.*
"	2·800 to 3·000	Erdmann.
Praseolite,	2·754	Thomson.*
Prasilite,	2·311	"
Prehnite,	2·900 to 2·953	Cresy.*
"	2·61 to 2·945	Morley.
Propione,	—1	Berzelius.
Pseudo-malachite,	4·20	Rammelsberg.
Psilo-melanite,	4·080 to 4·360	Haidinger.
"	4·145	Ure.*
Pumice-stone,	0·370 to 0·914	Brande.*
Pus,	1·030	Kirwan.
Puzzolana,	2·57 to 2·85	Erdmann.
Puschkitnite,	3·430	Bucholz.
Pycnite,	3·503 to 3·530	Thomson.*
Pyrallolite,	2·555 to 2·594	Nördenskiold.
Pyrargyllite,	2·1505	G. Rose.
Pyrochlore,	4·206 to 4·216	Thomson.
Pyrolusite,	4·819 to 4·70	Berthier.
"	4·7 to 4·9	Thomson.
Pyromorphite,	6·5781 to 6·9150	Klaproth.
"	5·560	Karsten.
"	7·009 to 7·050	Thomson.
Pyrope,	3·780	Cresy.*
"	3·718 to 3·946	"

Substances.	Density at 60° F.	Authority.
Pyrophysalite,	3·450	Cresy.*
Pyrorthite,	2·190	Berzelius.
Pyrosklerite,	2·740	Kobell.
Pyrosmalite,	3·081	H. Rose.
"	2·95 to 3·10	Rammelsberg.
Pyroxene,	3·233 to 3·349	Thomson.
ferruginous,	3·713	Gruner.
Pyroxylic,	0·824	Ure.*
or Wood Spirit,	0·798 at 68°	Dumas.
Pyruvic acid,	1·250	Thomson.
QUARTZ,	2·613 to 2·654	Beudant.
"	2·674	Haüy.
"	2·690	Mohs.
Kilpatrick,	2·525 (?)	Thomson.
Quinoleine,	+ 1	Gerhardt.
RAPHILITE,	2·850	Thomson.*
"	2·845	Hunt.
Resins, Animé,	1·0284	Brisson.
benzoin,	1·0284 to 1·0630	"
copal,	1·045	Moseley.*
"	1·059 to 1·071	Ure.*
"	1·069	Thomson.
dammara,	1·097 to 1·123	Brisson.
dragon's-blood,	1·196	"
" "	1·201	Moseley.*
elemi,	1·018	Brisson.
guaiacum,	1·2289	Brande.*
Highgate resin,	1·046	Thomson.
jalap,	1·010	Unverdorben.
lac,	1·139	Brisson.
labdanum,	1·186	"
mastic,	1·074	"
Maynas,	1·120	Lewy.
rosin,	1·080	Thomson.
sandarach,	1·060	"

Substances.	Density at 60° F.	Authority
Resins, tacamahac,	1·0463	Brisson.
Rhodalite,	2·000	Thomson.
Rhodochrome,	2·668	Tiedler.
Ricinoleic acid,	0·940	Säalmüller.
Ricottine,	1·055	Schubler.
dry,	1·355	"
Rionite,	5·560	Thomson.
Rochelle-salt,	1·749	Mitscherlich.
Rosemarine,	0·867	Kane.
Ruby, Brazilian,	3·531	Cresy.*
ballas,	3·646	"
Oriental,	4·284	"
spinelle,	3·525	Thomson.
"	3·57 to 3·76	Cresy.*
Rum,	0·9349	Ure.*
Rutile,	4·180	Klaproth.
"	4·209	Damour.
Rutilite,	3·1 to 3·5	Cresy.
Ryacolite,	2·581 to 2·589	"
SAHLITE,	3·231 to 3·256	D'Andrada.
Sal-ammoniac,	1·528	Thomson.*
Sal-gemme,	2·143	Moseley.*
"	2·257	Mohs.
Salicine,	1·1731	Piria.
Salicite,	2·666	Thomson.
Salicone,	1·0212	"
Salicylous acid,	1·1731	Graham.* [Gmelin.
Saliva,	1·0038 to 1·0043	Tiedemann and
"	1·0061 to 1·0088	Mitscherlich.
Sand, quartzose,	2·750	Tredgold.
river,	1·886	Belidor.
pit,	1·454 to 1·638	Tredgold.
Santonine,	1·247 at 70°	Thomson.*
Sap, birch,	1·004	John.
cow-tree,	1·0124	Thomson.*

Substances.	Density at 60° F.	Authority.
Sapphire,	3·951	Thomson.*
Oriental,	4·200	Moseley.*
"	3·991 to 3·994	Cresy.*
Brazilian,	3·131 to 4·083	"
Sapphirine,	3·4282	Stromeyer.
Sardonyx,	2·5951 to 2·6284	Cresy.*
Scapolite,	3·68 to 3·70	"
"	2·709 to 2·749	Thomson.
Scarbroite,	1·480	Vernon.
Scheelite,	5·95 to 6·07	Karsten.
Scheererite,	0·680	Macaire Princep.
Schorl,	3·452	Moseley.*
	3·0926 to 3·4520	Cresy.*
Schorlamite,	3·783	Shepard.
Scolegite,	2·214	Fuchs and Gmelin.
"	2·270	Brooke.
Scorilite,	1·708	Thomson.
Scorodite,	3·110	Damour.
"	3·162 to 3·300	Haidinger.
"	3·400	Bournou.
Scorza,	3·289	Thomson.
Selenic acid, con. solu.,	2·524	Brande.*
" "	2·600	Graham.*
Selenite.	2·3117	Cresy.*
"	2·322	Royer and Dumas.
"	2·3905	Thomson.
Selenium,	4·31	Boullay.
"	4·30 to 4·32	Berzelius.
granular,	4·796 to 4·805	Schaffgotsch.
vitreous,	4·276 to 4·286	"
Serpentine,	2·412	Thomson.
precious,	2·50 to 2·60	L. Gmelin.
Shale,	2·600	Moseley.
Shell, pearl,	2·190	Brewster.
oyster,	2·020	"

Substances.	Density at 60° F.	Authority.
Sideroschisolite,	3·000	Thomson.
Silica,	2·660	Kirwan.
Silicite,	2·666	Thomson.
Silicium,	+1	
Sillimanite,	3·1636	Thomson.
"	3·41	Bower.
"	3·20 to 3·357	(?)
Silvanite,	5·723	Reichenstein.
Silver, antimonial,	9·4406	Haüy.
chromate,	5·770	Playfair and Joule.
chloride, fused,	5·450	Gray.*
	5·552	Thomson.
ditto, native,	4·75 to 5·55	Klaproth.
fahl-ore,	5·007	Weissenbach.
glance,	7·196	Thomson.
iodide,	5·500	Filhol.
oxide,	7·140	W. Herapath.
"	7·147	Playfair and Joule.
"	7·249	Boullay.
nitrate,	3·521	Gray.*
"	4·336	Playfair and Joule.
phosphate,	7·300	Gray.*
selenide,	8·000	G. Rose.
sulphate,	5·410	Filhol.
"	5·222	Playfair and Joule.
"	5·340	Karsten.
sulphide,	6·850	"
"	7·200	Brande.*
"	5·5 to 5·6	Phillips.
telluric,	8·412 to 8·465	Thomson.
ore, dark-red,	5·8 to 5·9	"
light-red,	5·552	H. Rose.
Sinople,	2·691	Cresy.*
Sismondine,	3·564	De Lom.
Slate,	2·110	Moseley.*

Substances.	Density at 60° F.	Authority.
Slate,	2·512 to 2·888	Cresy, &c.*
Smalts,	2·440	Moseley.*
Smaragdite,	3·000	Cresy.*
Smithsonite,	3·584 to 3·598	Smithson.
Slag, iron,	2·905 to 4·183	Dr. Percy.*
Snow, including interstices,	0·041	
Soap, good commercial,	—1	
foreign Castile,	1·0715	Ure.*
English Castile,	0·9665	"
Soap-stone,	2·396 to 2·411	Thomson.*
Soda, anhyd.,	2·805	Karsten.
hydrated,	2·000	Brande.*
"	2·130	Filhol.
concent. solu.,	1·500	Dalton.
acetate,	2·100	Gray.*
arseniate,	1·736 at 39·1°	Playfair and Joule.
biborate,	1·730	" "
"	1·740	Kirwan.
"	1·757	Wattson.
carbonate,	1·454	Playfair and Joule.
"	1·423	Haidinger.
"	1·620	Brande.*
concen. solu.,	1·260 at 60°	"
"	1·107 at 46·5°	Anthon.
sesquicarb.,	2·112	Haidinger.
bicarbonate,	2·192	Playfair and Joule.
nitrate,	2·182 to 2·2606	" "
	2·188	Marx.
	2·200	Kopp.
	2·226	Karsten.
	2·260	Filhol.
phosphate,	1·525	Playfair and Joule.
pyro-phosphate,	1·836	" "
sulphate, anhyd.,	2·645	Thomson.
" "	2·730	Cordeir.

Substances.	Density at 60° F.	Authority.
Soda, sulphate anhyd.,	2·632	Karsten.
" "	2·629	Filhol.
crys.,	1·349	Thomson.
"	1·460	Gray.*
"	1·520	Filhol.
"	1·469	Playfair and Joule.
bisulphate,	1·800	Thomson.
"	2·742	Playfair and Joule.
sulphite,	2·950	Gray.*
tartrate,	1·980	Thomson.
Sodalite,	2·288	Hofmann.
"	2·295 to 2·378	Thomson.*
"	2·29 to 2·49	L. Gmelin.
Sodium, bromide,	2·340	Playfair and Joule.
" chloride,	2 011 at 39·1°	" "
" "	2·030	Unger.
" "	2·078	Karsten.
" "	2·150	Kopp.
" "	2·240	Filhol.
" " sat. solu.,	1·2046 at 66°	Karsten.
" " "	1·205 at 46·5°	Anthon.
" iodide,	3·450	Filhol.
" sulphide,	2·471	"
Sordawalite,	2·580	Thomson.*
Spar, fluor,	3·791	Moseley.
" calc.,	2·837	"
Spermaceti,	0·943	"
Sphærulite,	2·416 to 2·452	Breithaupt.
Sphene,	3·238 to 3·510	
Spherostilbite,	2·310	Beudant.
Spinelle,	2·523	Thomson.
" artif.,	3·548	Ebelman.
" natural,	3·523 to 3·585	"
Spirits of wine (*Sp. communis*), L. Ph.,	0·815 at 62°	Gray.*

Substances.	Density at 60° F.	Authority.
Spirits of wine, E. Ph.,	0·796 at 60°	Gray.*
D. Ph.,	0·810	"
Sp. com. tenuior L. and E. Phars.	0·920	"
D. Ph.,	0·9194	"
Spodumene,	3·115	Leonhard.
"	3·170	Haidinger.*
"	3·188	Thomson.
"	3·218	Moseley.*
Stalactites,	2·546	"
"	2·324 to 2·478	Cresy.*
Stannolite,	6·55 to 6·945	Berzelius.
Starch, potato,	1·530	Raspail.
Staurolite,	3·5 to 3·8	L. Gmelin.
"	3·693	Thomson.
Steam,	0·00076	Daniell.
Stearic acid,	1·0100	Chevreul.
Stearine,	—1 (?)	
Steel,	7·78 to 7·84	Thomson.
" soft,	7·833	Templeton.
" hardened,	7·816	"
" cast,	7·920	Schaffgotsch.
Steinkeilite,	2·6003	Stromeyer.
Sternmannite,	6·833	Zippe.
Stellite, of Beck,	2·836	Beck.
Stellite,	2·612	Thomson.
Stercorite,	1·6151	Th. Herapath.
Sternbergite,	4·2151	Haidinger.
"	4·250	Zippe.
Stibæthyl,	1·3244 at 61°	Lowig & Schweitz.
" bromide of,	1·954 at 63°	"
" chloride of,	1·540	"
Stilbite,	2·0 to 2·2	Phillip.*
"	2·13 to 2·143	Thomson.*
"	2·161	Descotils.
"	2·500	Moseley.*

Substances.	Density at 60° F.	Authority.
Stilpnomelan,	3·27 to 3·40	Glocker.
Stone:—Bath, or roe-stone,	1 975	Tredgold.
" "	2·494	Kirwan.
" blue lias,	2·467	Tredgold.
" brick,	2·000	Templeton.
" Bristol or mountain limestone,	2·554	"
	2·640	Moseley.
	2·510	Tredgold.
" Burford,	2·049	"
" Caen,	2·108	R. Tredgold.
" chalk,	2·781	Templeton.
" Clitheroe limestone,	2·686	Watson.
" Collalo,	2·040	Tredgold.
" "	2·423	Rennie.
" Craigleith sandstone,	2·360	Tredgold.
" "	2·452	Rennie.
" Cutler's,	2·113	Moseley.
" Dundee,	2·517	Tredgold.
" "	2·530	Rennie.
" Granite,	which see.	
" Grinding,	2·143	Tredgold.
" Kentish-rag,	2·675	"
" Ketton roe-stone,	2·058	"
" "	2·498	Kirwan.
" Liege,	2·636	Cresy.*
" Limerick limestone,	2·598	Rennie.
" Lorraine,	2·529	Cresy.*
" Marble,	which see.	
" Millstone,	2 484	Templeton.
" Paving,	2·4158	"
" "	2·708	Moseley.*
" Pannarth limestone,	2·653	Watson.
" Portland roe-stone,	2·113	Tredgold.
" "	2·423	Rennie.
" "	2·570	Templeton.

Substances.	Density at 60° F.	Authority.
Stone, Pumice,	0·629	R. Tredgold.
" Purbeck,	2·599	Rennie.
" "	2·601	Templeton.*
" "	2·680	Watson.
" Rotten,	1·981	Cresy.*
" Ray,	2·470	"
" Sandstone, for paving,	2·4158	"
" Scythe,	2·609	"
" Touch,	2·415	"
" Whinstone,	2·760	Watson.
Stromnite,	3·903	Trail.
Strontia, anhyd.,	3·0 to 4·0	H. Davy.
" "	3·932	Karsten.
" "	4·611	Filhol.
" crystal hyd.,	3·635	"
" do. with 9 at aq.,	1·396	"
" carbonate of,	3·605	Mohr.
" "	3·6245	Karsten.
" "	3·6600	Gray.*
" "	3·6750	Moseley.*
" calcareous, sulphate of,	2·750	Thomson.
" nitrate of, anhyd.,	2·857	Filhol.
" " crys.,	2·704	Playfair and Joule.
" sulphate of,	3·588	Karsten.
" "	3·770	Filhol.
" "	3·958	Moseley.*
Strontianite,	3·713	Thomson.
Strontium, chloride of,	2·960	Filhol.
" "	2·803	Karsten.
" " crys.,	2·015	Playfair and Joule.
Struvite,	1·700	Ulex.
Styrole,	0·924	Blyth & Hofmann.
Succineupion,	0·645 at 43°	Elsner.
Succinic acid, hyd.,	1·550	Brande.*
Sugar, cane and beet,	1·5 to 1·6	"

Substances.	Density at 60° F.	Authority.
Sugar, cane and beet,	1·5629	Thomson.*
" "	1·6065	Fahrenheit.
" "	1·5929 at 39·1°	Playfair and Joule.
" grape,	1·500	Proust.
" " syrup of,	1·215 (?)	"
" milk,	1·543	Brande.
" "	1·5339 at 39·1°	Playfair and Joule.
Sulphur, native,	1·97 to 2·08	Brande.*
"	1·989 to 2 050	Karsten.
"	1·898	Fontenelle.
"	2·027	Osann.
"	2·072	Mohs.
"	2·066	Marchand.
flowers of,	2·086	Le Royer & Dumas
dichloride of,	1·686	Marchand.
"	1·687	Dumas.
chloride,	1·620	"
"	1·625	Marchand.
Sulphuric acid, anhyd.,	1·97 at 65°	Bussy.
"	1·946 at 55°	Morveau.
Nordhausen,	1·896	Thomson.
1-hyd.,	1·848	H. Davy.
oil of vitriol,	1·8455	Brande,* &c.
2-hyd.,	1·7800	Chaptal.
"	1·7840	Wackenroder.
3-hyd.,	1·6321	Ure.
Sulphurous acid, liq.,	1·420	Faraday.
" "	1·450	Bussy.
Sussanite,	6·3 to 6·5	Brooke.
Sylvanite,	6·343	Cresy.*
Syenite,	2·621	Tredgold.*
"	2·5 to 3·0	Portlocke.*
Synovia,	1·050	Dupuytren.
Synaptase or emulsine,	+ 1	Dumas.

Substances.	Density at 60° F.	Authority.
Tachylyte,	2·7144	Klett.
Talc,	2·7 to 2·8	Cresy.*
"	2·697	Thomson.*
Tallow,	0·941	Moseley.*
Tankelite,	4·5577	Thomson.
Tantalic acid,	7·0 to 7·1	H. Rose.
ignited,	8·2	"
Tantalite,	7·236 to 7·655	Berzelius.
"	7·264	Nordenskiöld.
"	7·963	Ekeberg.
Tautolite,	3·865	Breithaupt.
Tartar,	1·849	Cresy.*
Tartaric acid,	1·600	Gray.
Teeth, enamel of,	2·688 to 2·843	Thomson.*
ivory of,	1·892 to 2·105	"
Tellurium, graphic ore of,	5·723	Reichenstein.
Nagyag ore of,	6·840	Thomson.*
native,	5·7 to 6·1	W. Phillips.
sulpho-plumbifer,	6·840	Berthier.
white ore of,	10·673	Reichenstein.
Tennantite,	4·375	R. Phillips.
Terpinole,	0·852	List.
Tereben, bromide,	1·978	Deville.
chloride,	1·360	"
hydriodate,	1·084	"
hydrobrom.,	1·021	"
hydrochlor.,	0·902 all at 68°	"
Terra-japonica,	1·398	Cresy.*
Thenardite,	2·730	Thomson.*
Thialdine,	1·1910	Wöhler and Liebig.
Thomsonite,	2·290 to 2·3696	Thomson.
Thorina,	9·402	Berzelius.
Thorite,	4·630	Thomson.*
Thujon,	— 1	Schweizer.
Thulite,	3·1055	Thomson.

Substances.	Density at 60° F.	Authority.
Tile, common,	1·815	Belidor.
"	1·853	R. Tredgold.
Tin, chloride,	2·759 at 39·1°	Playfair and Joule.
peroxide,	6·640	W. Herapath.
"	6·712	Playfair and Joule.
"	6·900	Boullay.
" hyd.,	4·933	Berzelius.
protoxide,	6·666	W. Herapath.
pyrites,	4·35 to 4·76	Klaproth.
sulphide,	5·267	Doullay.
Titaniferous iron,	4·66 to 4·78	Von Kobell.
" "	4·545	Klaproth.
" "	3·153	Möhl.
Titanic acid,	4·128	Brande.*
	3·899 to 3·960	Rose.
ignited,	4·206 to 4·254	"
Titanium, native,	5·300	Wollaston.
Toad-stone,	2·921	Watson.
Tolene,	0·858	Kopp.
Topaz,	3·499	Haidinger.
"	3·641	Lowry.
" oriental,	4·061	Moseley.*
	3·951	Thomson.
	4·016	Cresy.*
Tourmaline,	3·0 to 3·06	Thomson.*
"	3·076	Haidinger.
"	3·14	Leplay.
"	3·059 to 3·246	Gmelin.
Tourquoise,	2·6296 to 3·2500	Thomson.*
"	3·000	Moseley.*
Treacle,	1·400	Ure.*
Tremolite,	2·9257 to 3·200	Haüy.
Triphyline,	3·600	Fuchs.
Tripoli,	1·9 to 2·2	Ure.*
Troostite,	4 0 to 4·1	Thomson.

Substances.	Density at 60° F.	Authority.
Truesite,	2·558 to 2·628	Thomson.*
Tschewkinite,	4·500	Hermann.
Tufa, Roman,	1·217	Rondelet.
Tungstic oxide,	12·110	Karsten.
acid,	5·274	W. Herapath.
"	6·120	De Luyert.
"	7·139	Karsten.
ochre,	6·0009	Silliman.
ULTRAMARINE,	2·360	Moseley.*
Umber,	2·200	Ure.*
Unionite,	3·298	Silliman.
Uralite,	3·150	G. Rose.
Uranic oxide, hyd.,	5·926 at 59°	Malaguti.
Uranite or Uran-mica,	2·990	Moseley.*
	3·120	Champeaux.
	3·198	Th. Herapath.
Uranium, native protoxide,	6·468	Thomson.*
" " "	6·940	Richter.
Uranoso-uranic oxide,	7·193	Karsten.
Urea,	1 350	Prout.
	mean.	
Urine, healthy human,	1·017 to 1·0123	Becq. Thomson.
" "	1·020	Prout. Bird.
" "	1·0204	Chussat.
" "	1·030	Brande.*
" "	1·0016 to 1·0388	Chassat.
" "	1·0050 to 1·033	Cruickshank.
" "	1·010 to 1·038	Lecanu.
	mean.	
of man,	1·0189	Becquerel.
of woman,	1·0151	"
of cow,	1·035	Boussingault [uelin.
of horse,	1·03 to 1·05	Fourcroy & Vauq-

Substances.	Density at 60° F.	Authority.
Urine of horse,	1·0293	Prout.
"	1·064	Boussingault.
Uwarowite,	3·41	Komonen.
VALERIANIC acid,	0·944	Trommsdorff.
Valero, aceto-nitril,	0·790	Gluckenberger.
"	0·810	Schlieper.
"	0·813	Gluckenberger.
Vanadite,	6·99 to 7·23	Johnston.
Valyl,	0·894 at 65°	Kolbe.
Varvicite,	4·283 to 4·531	Phillips.
Vauquelinite,	6·8 to 7·2	Berzelius.
Vermiculite,	2·5252	Thomson.
Vesuvian,	3·420 to 3·575	Moseley.*
"	3·339 to 3·407	Cresy.*
Vesuvian-idocrase,	3·349 to 3·990	Thomson. [zeaux.
Villenite,	4·154	Delesse & Descloi-
Vivianite,	2·661	Thomson.*
Vinegar, Revenue Pr.,	1·0085	Moseley.*
" Malt,	1·014	Ure.
Volborthite,	3·550	Phillips.
Voltzine,	3·660	Thomson.
Vulpinite,	2·8787	Hauy.
WACKE,	2·55 to 2·90	Ure.*
Wad,	2·314 to 3·700	Phillips.
Wagnerite,	3·068 to 3·130	Fuchs.
Warwickite,	3·00 to 3·14	Shepard.
Water,	1·000	
" sea,	1·026 to 1·028	Brande.*
" Dead sea,	1·153 to 1·245	
Wavellite,	2·337	Haidinger.
"	2·253	Gregor.
"	2·361	Richardson.
Wax, bees',	0·960	Brande.*
Wax, bees'	0·964	Moseley.*
" Brazilian,	0·980	Brande.*
" Japan vegetable,	0·970	Thomson.
" white,	0·968	Moseley.*
" "	0·8203 to 0·9666	Fabroni.
" shoemakers'	0·897	Moseley.*
Weisserite,	2·868	Thomson.*
Wermelandite,	3·383 to 3·538	Berzelius.
Whet-slate,	2·722	Ure.*
Whey, cows',	1·019	Moseley.*
Wichtyn,	3·030	Laurent.
Williamsite,	3·935	Thomson.*
Wine, Bordeaux,	0·993	Moseley.*
" Bucellas,	0·979	Ure.*
" Burgundy,	0·983 to 0·9854	"
" "	0·991	Moseley.*
" Calcavella,	0·979	Ure.*
" Cape, Madeira,	0·979	"
" Champagne, rose,	0·986	"
" " white,	0·9845 to 0·9970	"
" Constantia,	1·081	Moseley.*
" "	0·977	Ure.*
" Cote-roti,	0 9849	"
" Currant,	0·9769	"
" Elder,	0·9876	"
" Frontignac,	0·9845	"
" Gooseberry,	0·9855	"
" Hermitage, red,	0·9849	"
" " white,	0·9799	"
" Hock,	0·9829 to 0·9887	"
" Lisbon,	0·9784	"
" Madeira,	0·9733 to 0·9781	"
" Malaga,	0·980	"
" "	1·022	Moseley.*

Substances.	Density at 60° F.	Authority.
Wine, Muscat.,	0·979	Ure.*
" Port,	0·972 to 0·976	"
" Raisin,	0·972	"
" Roussillon,	0·980	"
" Schiraz,	0·982	"
" Sherry,	0·977 to 0·9791	"
" Syracuse,	0·982	"
" "Vin de Grave,"	0·9845	"
Withamite,	2·857	Thomson.
"	3·137	Turner.
Witherite,	4·292	Hauy.
"	4·298	Thomson.
"	4·301	Mohs.
Wohlerite,	3·410	Shepard.
Wolfram,	7·191 to 7·544	Schaffgotsch.
"	7·002	Richardson.
Wollastonite,	2·850 to 2·876	Thomson.
Wood-ashes, with insterstices,	0·933	Tredgold.
Wood, petrified,	2·341	"
" "	2·011 to 2531	Th. Herapath.
Woods:—Ash,	0·845	Templeton.*
" Alder,	0·800	
" Beech,	0·852	
" Cedar, American,	0·561	
" Chestnut,	0·610	
" Cork,	0·240	
" Deal,	0·590	
" Elm,	0·673	
" Fir,	0·546 to 0·753	
" Larch,	0·530	
" Mahog., Spanish,	0·800	
" " Honduras,	0·637	
" Oak, African,	0·944	
" " Dantzic,	0·756	

Substances.	Density at 60° F.	Authority.
Woods:—Oak, American,	0·672	Templeton.*
" " English,	0·934	
" " Plane,	0·640	
" Pine, pitch,	0·660	
" " yellow,	0·461	
" Poplar,	0·383	
" Poonah,	0·640	
" Spruce,	0·551	
" Sycamore,	0·604	
" Teak,	0·750	
" Walnut,	0·671	
Xanthite,	3·201 to 3·221	Thomson.
Xanthophyllite,	3·0 to 3·1	Gmelin.
"	3·044	G. Rose.
Xylite,	0·816	Gmelin.
Yttria,	4·842	Ekeberg.
" native phosphate,	4·557	Thomson.
Yttrocerite,	3·447	"
Yttroilmenite,	5·398 to 5·45	Hermann.
"	5·6142	Wornam.
"	5·6170	H. Rose.
Yttrotantalite,	5·130	Cresy.*
" black,	5·395	Thomson.*
" "	5·670	Peretz.
" yellow,	5·882	Ekeberg.
" ignited,	6·400	Peretz.
Zeilanite,	3·6 to 3·8	Abich.
Zeolite,	2·718	Moseley.*
Zeuxite,	3·051	Thomson.
Zinc, chloride of,	1·577	Gray.*
" blende,	4·049	Thomson.*
" "	3·90 to 4·07	Karsten.
" ferruginous blende,	3·2 to 3·6	Bouis.

Substances.	Density at 60° F.	Authority.
Zinc, ferruginous blende,	3·850	Bouis.
" oxide of,	5·430	Mohs.
" "	5·600	Boullay.
" "	5·612	Filhol.
" "	5·734	Karsten.
" " crys.,	5·5298	Messrs. Herapath.
" " "	6·000	Vernon.
" " hydr.,	3·053	Filhol.
" sulphate,	1·930	Gray.
" "	2·036	Filhol.
" " anhyd.,	3·400	"
" sulphide,	3·923	Karsten.
" red,	5·432	Thomson.*

Substances.	Density at 60° F.	Authority.
Zinc, selenide,	5·560	Thomson.*
Zinkinite,	5·303	G. Rose.
Zircon,	4·681	Thomson.
"	4·721	Lowry.
"	4·505	Haidinger.
"	4·615	Henneberg.
" ignited,	4·710	"
Zirconia,	4·300	Klaproth.
"	4·350	Vauquelin.
Zoisite,	3·320 to 3·3207	Klaproth.
"	3·170 to 3·430	Hermann.
Zurlite,	3·274	Ramondini.

CHEMICAL TABLES,

NOTES *on the* TABLE *of* DENSITIES.

ACETIC ACID.—Specific gravity is not a certain criterion of the strength of acetic acid, when the latter contains more than about 34½ per cent. of water. —*Mollerat.*

The acetometer of the Messrs. Taylor has for its basis the strength of proof acid (Pr. v.), called by the manufacturer No. 24.

Table, by the Messrs. Taylor, showing the proportion of real acid per cent. at different densities :—

Pr. V.—1·0085, 5%; 1·017, 10%; 1·0257, 15%; 1·032, 20%; 1·047, 30%; 1·058, 40%.

When acetic acid is converted into acetate of lime, the decimal fraction of the density is very near doubled;—thus, 1·009 in pure acetic acid becomes 1·018 in acetate of lime.—(*See Vinegar.*)

ÆTHER.—*Table, showing the specific gravity of mixtures of alcohol and ether; by Dalton.*—Pure ether, 0·72(?); 90+10, 0·732; 80+20, 0·744; 70+30, 0·756; 60+40, 0·768; 50+50, 0·780; 40+60, 0·792; 30+70, 0·804; 20+80, 0·816; 10+90, 0·828; 0+100, 0·83 (Spirit).

ALCOHOL.—For tables of the density of various mixtures of alcohol and water, *see* "Brande's Manual," "Ure's Dictionary," and other works.

ALLOYS.—Alloys which possess a density *greater* than the mean of their constituents :—

Gold with antimony, bismuth, cobalt, tin, or zinc; silver with antimony, bismuth, lead, tin, or zinc; lead with antimony; platinum with molybdenum; palladium with bismuth; copper with bismuth, palladium, tin, or zinc.

Alloys which possess a density *less* than the mean of their constituents :—

Gold with copper, iron, lead, iridium, nickel, or silver; silver with copper or lead; iron with antimony, bismuth, or lead; tin and antimony, lead, or palladium, nickel, and arsenic; zinc and antimony.—*Thénard.*

AMMONIA.—*See* "Tables," by Ure, Dalton, Davy, &c.

"Ure's Table," is generally considered to be the most correct.

BARLEY.—If not more than five "*pickles*" (or grains) per hundred float, when unmalted barley is thrown into water, it is considered by tradesmen to be a good sample of grain; if more, the contrary. After malting, the grain becomes specifically lighter, and when thrown into water, will float in a longitudinal position; in good malt, only about five pickles per hundred will sink; grain that has been partially malted will remain perpendicularly suspended in the water.

BEER.—The rule employed by Mr. Warington for converting the saccharometric indication (by Richardson's instrument) of the wort into real specific gravity, is as follows:—Divide the saccharometer indication by 360, and then add one. Example—

$$36 \div 360 + 1{\cdot}00 = 1{\cdot}1 \text{ sp. gr.}$$

Richardson's saccharometer indicates by how many pounds a barrel of wort of a certain density is heavier than a barrel of pure water (viz., 360 lbs.) To convert saccharometric indication into real gravity, add the number indicated (say x) to 360, and make the following simple calculation :—

$$360 : 360 + x :: 1 : \text{true density.}$$

The scale of Dicas's instrument is nearly as 5 to 2 of Richardson's; *i. e.* 80 by the latter are about equal to 200 by the former.

Allan's saccharometer indicates the true specific gravity.

BLOOD.—The density of the blood, and of the serum of the blood, is increased in plethora, cholera, &c., and diminished during pregnancy, and in pneumonia, bronchitis, pleuritis, tubercular phthisis, fever (?), and chlorosis.

THE EARTH.—The density of the earth is supposed to increase in an arithmetical progression at the rate of about ·38 for every 100 miles, as we penetrate through the exterior crust towards the centre.

GAS.—A diffusion experiment affords the elements for calculating the specific gravity of a gas.

$$\text{The specific gravity} = \left(\frac{A}{G}\right)^2$$

Where G is the measure of gas submitted to diffusion, and A the measure of return air.—*Edinb. Phil. Trans.* XII, 222.

One hundred cubic inches of dry air, at 29·92 inches Bar., weigh 32·58864 grs. at 32° F., and 30·82926 grs. at 60° F.—*Regnault.*

GLASS.—The density of annealed glass is greater than that of the unannealed. The phenomena of devitrification are always accompanied by an increase in density; thus, soda glass being =2·485, the devitrified glass is =2·503.—*Splittgerber.*

HYDROCHLORIC ACID.—*See* tables by Davy, Thomson, Ure, Kirwan, and Dalton. Ure's results are considered the most accurate.

HYDROCYANIC ACID.—0·957, 16%; 0·9768, 10·6%; 0·9815, 9·1%; 0·984, 8%; 0·987, 7·3%; 0·989, 6·4%; 0·99, 5·8%; 0·9923, 5·0%; 0·994, 4%; 0·9958, 3%; 0·9974, 2%; 0·9979, 1·6%.—*Dr. Ure.*

MAGNESIA (SULPHATE OF).—For a table, by Anthon, *see* Gmelin's Handbook (English trans.)

NITRIC ACID.—Tables by Ure, Thomson, Kirwan, and Dalton, are contained in most of the manuals. Ure's table appears to be the most correct.

OILS (FIXED).—The zero of the scale in the so-called Elaëometer is placed where the instrument would float in pure oil of poppy seeds; the space between this point and that which marks the density of pure olive oil is generally divided into 50 degrees. The density of pure almond oil is about equal to 38 or 38½ degrees by this scale. The Oleometer of M. Laurot is so graduated as to sink to zero in pure colza oil (heated to 212° F.); to 210° in rapeseed oil; to 124° in poppy oil; to 83° in fish oil; and to 136° in oil of hempseed.

PHOSPHORIC ACID.—Sp. gr. 1·85, 50% anhyd. acid: 1·6, 40%; 1·39, 30%; 1·23, 20%; 1·1, 10%.—*Dalton.*

POTASH.—For tables showing the proportion of caustic potash, and hydrate of potash, contained in lyes of different strength, *see* the works of Ure, Brande, Gmelin, &c. Ure's table appears to be the most accurate.

POTASH (CARBONATE OF).—For table, by Tünnermann, *see* works of Brande, Gmelin, &c.

POTASH (CHROMATE OF).—S.G. 1·28, 50%; 1·21, 33%; 1·18, 25%; 1·15, 20%; 1·12, 16%; 1·11, 14%; 1·1, 12%.—*Dr. Ure.*

PYROXYLIC SPIRIT.—For table, *see* Ure's Dictionary of Arts, &c.

ROOT-CROPS.—The relative densities of different roots or tubers, are stated by Mr. Hyett, to be as follows:—

Turnips:—Pomeranian globe, 889; Green round, 905; Border imperial, 932; —average, 908·57.

Swedes:—Purple-topped, 949; Green-topped, 952; Skirving's, 972;—average, 957·67.

Mangold-wurzel:—Long-red, 995·25; Red-globe, 1005·7; Yellow-globe, 1014·6;—average, 1005·18.

Potatoes.—Rohan, 1081 to 1089·95; Purples, 1091 to 1102; Welsh-kidney, 1107 to 1108;—average, 1096·49.

The specific gravity of small roots appears generally to exceed that of large roots. Mr. Hyett says, "That the determination of the densities of root-crops, affords an easy though rough method of estimating their relative powers of nourishment."(?)

SODA.—For tables, by Richter and Tünnermann, of the proportion of hydrate of soda and ahhydrous soda, contained in lyes of different densities, *see* the works of Gmelin, Brande, Ure, &c.

The following table is by Dalton, and shows the percentage of NaO.

Sp. G. 1·85, 63·6%; 1·72, 53·8%; 1·63, 46·6%; 1·56, 41·2%; 1·5, 36·8%; 1·47, 34%; 1·44, 31%; 1·40, 29%; 1·36, 26%; 1·32, 23%; 1·29, 19%; 1·23, 16%; 1·18, 13%; 1·12, 9%; 1·06, 4·7%.

SODA (CARBONATE OF).—For table, *see* Gmelin's Handbook.

SODA (NITRATE OF).—*See* Richter's tables; Stoichiometrie 3·164.

SODA (SULPHATE OF).—*See* Brandes and Gruner, Br. Arch. 22·148.

SODIUM (CHLORIDE OF).—The proportions of salt in solutions of different densities, at 62° F., is shown below.

S.G. 1·0283, 1–24th; 1·0275, 1–25th; 1·027, 1–26th; 1·0267, 1–27th; 1·025, 1–28th; 1·0233, 1–30th; 1·0185, 1–39th; 1·0133, 1–44th; 1·0105, 1–56th; 1·004, 1–108th; 1·0023, 1–162d.

[Calculated by Mr. Kirwan, from Watson's results.]

SUGAR.—According to Dr. Ure, if the decimal part of the number representing the specific gravity of syrup, be multiplied by 26, the product will denote very nearly the quantity of sugar per gallon in pounds weight, at the given sp. gr.

Table, by Dr. Ure, showing the percentage of sugar, in saccharine solutions of different densities :—

Sp. Gr. 1·326, 66 666⅔ sugar; 1·231, 50% ; 1·1777, 40% ; 1·144, 33·333⅓% ; 1·134, 31·25° ; 1·125, 29·412⅔% ; 1·111 26·316⅔% ; 1·1045, 25% ; 1·0905, 21·74⅔% ; 1·082, 20% ; 1·0635, 16·666⅔% ; 1·05, 12·5% ; 1·0395, 10%.

For more extensive tables, *see* the different chemical manuals; also, Evan's, Porter's, and Dutrone's works on the Sugar Manufacture.

At 1·342, syrup of the cane contains 70% of sugar; at the same density syrup of starch sugar contains 75½ per cent.—*Ure.*

For a table of the densities of alcoholic solutions of sugar, *see* Ure's Dictionary of Arts, Manufactures, &c.

SULPHURIC ACID.—For tables, by Parkes, Ure, Bineau, &c., *see* Ure's Dictionary, Gmelin's Handbook, Parnell's Applied Chemistry, and other manuals.

Bineau's table is said to be the most correct, but as the results are calculated to 32° F., Ure's table is the one most commonly accepted.

URINE.—To determine the proportion of solid matters in urine, multiply the difference between the density of the urine and that of water by 2·58 (Dr. Henry), or by 2·33 (according to Christison), the product shows the quantity of solid matters in 1000 grs. of urine. Thus, giving a urine of 1·004 sp. gr.: 1004—1000=4, which, multiplied by 2·58, gives 10·32 as the weight in grains of solids in 1000 grs. of urine. According to Becquerel, the proportion of sugar in a specimen of diabetic urine may be ascertained by using the factor 1·65 as above. Millon says, that "the second and third figures after the point (in the density) express with tolerable exactness the quantity of urea in 1000 parts of the urine. Thus, urine of 1·011 contains about 11 parts in 1000 of urea. In the urine of animals and pathological urines, however, M. Millon admits that this correspondence is no longer observed. The density of the urine is generally below the normal standard in *Diabetes insipidus* (1·003 to 1·005—Percy), hysteria, Bright's disease (?), chlorosis, and jaundice (?); and above, in *Diabetes mellitus* (1·032 to 1·048), erysipelas, fever, bronchitis, hæmoptysis, and other inflammatory diseases. It is generally higher in the afternoon (1·023 to 1·028) than in the forenoon (1·017 to 1·022), evening (1·019 to 1·028), or night, (1·012 to 1·025.)

VINEGAR.—Vinegar of malt, of a density of 1·014, becomes only 1·023 when converted into acetate of lime; ·005 of its density is due to mucilaginous matter. —*Ure.*

WATER.—The temperature at which pure water attains its greatest density, according to different observers, is as follows :—

38° F., *Dalton;* 38·75°, *Stampfer;* 38·8°, *Rumford;* 38·804°, *Muncke;* 39°, *Sir C. Blagden—Gilpin;* 39·101°, *Playfair* and *Joule;* 39·176°, *Despretz;* 39·38, *Hällstrom;* 39·5, *Hope:* 40°, *Lefebvre Gineau;* 41°, *Deluc.*

Despretz's determination is generally believed to be the most correct.

Sea-water (from the Southern Ocean), according to Bladh, attains its maximum density at 36·59° F.

WOODS.—The densities given in the table have reference to the dry and well-seasoned woods, in their natural condition.

The true specific gravities of these woods (*i. e.* when the air in the interstices of the wood has been expelled) are, according to Count Rumford, as follows :—

Birch, 1·4848; beech, 1·5284; elm, 1·5186; fir, 1·4621; lime, 1·4846; maple, 1·4599; oak, 1·5344; poplar, 1·4854.

CHAPTER IX.

MEASURES AND MEASURING.

Measuring of Fluids.—When great accuracy is required in the estimation of fluids, their weight is determined; but in ordinary operations, the amount of their volume is obtained by the employment of vessels purposely prepared and graduated with care and precision.

These vessels, or *graduates* as they are called, are generally of two forms, those for the larger operations being cylindrical, as shown by Fig. 101. This shape combines both strength and convenience. For the smaller (ounce or drachm) graduates the conical form, Fig. 102, is preferable, as giving greater facility, by its smaller surfaces, for accurately estimating minute volumes.

Fig. 101.

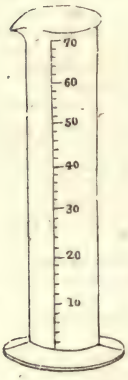


Fig. 102.

Graduation.—For the large measures, the imperial pint is the usual integer. To graduate a vessel to this extent, take a glass balloon, counterbalance it, and weigh therein accurately one pint imperial, 34·659 cubic inches (8750 grs.), of distilled water, at the temperature of 62° F., and at 30 inches of barometric pressure. After the vessel has remained undisturbed upon a level shelf, sufficiently long for its contents to acquire a smooth steady surface, scratch upon the neck the exact line to which the liquid rises. The narrower the neck of the flask the greater the facility in noting this point without liability of error. This weighed quantity of water is then to be transferred to the proof glass, under process, of form as shown in Fig. 101. After the water has settled, and presents a smooth calm surface, its level is to be scratched accurately upon the exterior of the glass, either with a diamond-point or a sharp file. A reliable pint measure is thus obtained, to graduate which into its subdivisions of ounces and drachms, it is only necessary to

take the weights of these fractions of the pint, and proceed in manner as above directed. So likewise, the vessel can be graduated to pint divisions, in number as many as its capacity will admit, by multiplying the weights of water, and adding them to those previously measured, noting the level of each with the diamond.

The imperial pint is larger than the wine pint of 16 fluid-ounces, in the ratio of 6 to 5, and, therefore, its subdivisions must number 20, and severally of 1·73296 cubic inches capacity. This makes a discrepancy, the inconvenience of which can be remedied by having a second scale upon the same glass, showing their relative values. The only disadvantage is the trouble of a second graduation, which is, however, compensated for in the convenience of the first scale, each division of which, unlike the fluid-ounce of the wine pint, represents a fluid-ounce exactly, weighing one ounce avoirdupois of distilled water=437·5 grains.

The plan of graduating the pint, itself estimated as above, into its subdivisions by apportioning its height into the requisite number of equal parts, by means of a rule, will only answer for vessels of uniform diameter throughout, and which are only intended for the grosser operations of measuring.

Those graduates, which are intended for nice purposes, should also have a third scale graduated in cubic inches. The cubic inch equals 252·458 grains of distilled water, at temperature and pressure the same as above, and a measure or bottle of this capacity should be prepared and kept ready for use. As there is sufficient room upon the glass for all these scales without the necessity of crowding them together,—there should be an equal interval between them.

To graduate a vessel to the litre of the French standard, substitute 1 kilogramme for the 8750 grains distilled water, and proceed as above, making the subdivisions pro rata.

The graduates and cubic inch bottles are less to be relied on when purchased than when carefully graduated by the operator himself, and they should never be used in important experiments without having been previously verified.

For the graduation of the ounce and drachm measures, and, indeed, all vessels of small diameters and capacities, such as tubes and the like, the divisions of which must necessarily for

want of space closely approximate to each other, mercury is much preferable to water. Mercury gives a more level and distinct surface than water, and not being attracted by the sides of the vessel, allows a greater accuracy in making the subdivisions, especially in very narrow tubes. The addition of one grain of lead to every 4000 grains of quicksilver flattens the surface, and greatly facilitates the reading of the level; but it must be otherwise pure and free from dross and film. A cubic inch of pure mercury, according to Faraday, weighs 3425·35 grains, at 62° F.

There should be a series of these graduated glasses, ranging from a double pint down to a drachm.

For the tubes and other vessels used in analytic research, the decimal divisions are both convenient and necessary. If a cubic inch is to be divided into tenths and hundredths, the former are graduated by the space occupied in the tube by the one-tenths (342·50 grs.) of a cubical inch of mercury, and each tenth division coincident with the level of the metal within, is marked upon the scale with the file or writing diamond. So also, in like manner, are the hundredths graduated by substituting 34·25 grs. (the hundredth of a cubic inch at 62°) for the 342·50 grs. mercury.

To give a clear idea of the mode of preparing a measure with mercury, let us suppose that a tube is to be graduated to cubic centimetres of the French standard. In the first place, a narrow strip of white paper, with a line ruled down its centre, is to be pasted lengthwise upon the side of the glass to be graduated, the length of the paper of course corresponding with the height of the glass. 13·59 grammes of mercury are next to be accurately weighed out, and this quantity, which represents a cubic centimetre, is to be poured into the tube, held vertically by a support similar to A, in Fig. 115. After the vessel has stood long enough for the liquid to become quiet and assume a smooth surface, its level is noted down, and its corresponding height marked with ink upon the paper slip. The space which this bulk of quicksilver occupies in the tube equals a cubic centimetre, and when accurately noted, may serve as a standard for the graduation of vessels of larger capacity; for these cubic centimetral divisions can be multiplied, merely by multiplying this given bulk of mercury, and noting and marking upon the paper the level of each addition as its surface becomes smooth. Ten times the

above weight of mercury gives a decimetral division, and one-tenth of it a millimetral division, and thus we have an easy mode of enlarging or diminishing the subdivisions of the scale. The ink marks are subsequently sunk into the glass with the diamond or file, or, still better, by the action of fluoric acid, as will be described directly.

By having the tubes accurately graduated so that their divisions exactly correspond with the weights of the balance, we acquire the convenience of calculating at once the weight of gases from their measured volume.

The plan of consecutive weighings, involves a good deal of trouble and labor where large vessels are being prepared, and hence, in such cases, the convenience of this mode of multiplying the divisions by an accurately adjusted measure.

In marking the scale, let those lines designating the tenths extend in width a little beyond those denoting the twentieths, and these latter, in their turn, a little beyond those expressing the hundredths. Fig. 101 represents a graduated glass with a properly written scale, upon which the tenths are shown by figures.

As these glasses are to be standard graduates for a variety of purposes in the laboratory, the scale should be indelible, or etched upon the glass. For this purpose the paper scale must be covered with a thin transparent film of melted white wax. When the wax has cooled and hardened, the lines and figures are graved out of the paper with a sharp-pointed style or burin, and the exposed surfaces of the glass subjected to the action of fluohydric acid, as directed at p. 79. This done, and the wax scraped off, the etched portions show out distinctly, and are better defined than if they had been scratched, as is sometimes done, with the diamond-point or file.

Be careful that the subdivisions conform accurately among themselves, and in the aggregate precisely with their integer. The volumes, as expressed by the lines on the scale, should also exactly agree with their corresponding weights, for upon these conditions depends the accuracy of results.

Tubes for eudiometry, Fig. 103, and proof-glasses for alkalimetry, Fig. 104, and all other vessels used in chemical operations for measuring, are graduated in like manner. The bell glasses (Fig. 85) for which and all large vessels, water is preferable,

should be graduated into double cubic centimetres, so that every divisional line may correspond to two centimetres; and the tubes into double cubic millimetres, so that every line may correspond to two cubic millimetres.

Fig. 103.

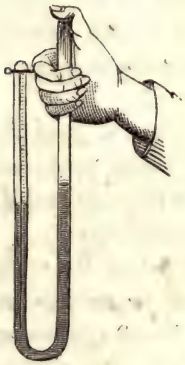


Fig. 104.

Dr. Henry proposes, as a quick and accurate method of graduating tubes for eudiometry, &c., to have a standard tube, 0·08 of an inch in diameter, and carefully divided into 10 equal parts, of 10 grains of mercury (60° F.) capacity each. This tube (Fig. 105) is a graduated pipette, fitted with a stop-cock and air-screw to promote its efficiency. It serves to measure or weigh out a standard measure of mercury in successive tenths or hundredths, as may be required, and according as it may be graduated.

Fig. 105.

The vessels should be of clear glass. The tubes must be thick, and strong enough to support the weight of their full contents of mercury. For the convenience of closing their mouths with glass disks, their ends may be ground flat and even.

In all operations of graduation, the waste of mercury is avoided by working over a porcelain plate, or, what is better, the mercury trough, Fig. 115. The metal may be conveyed to the vessels in the pipette, Fig. 107, which enables the addition or removal of minute portions, as the case may require.

The requirements of the laboratory call for an assorted stock of graduated tubes and proof-glasses, varying in diameter from a quarter to two inches.

Below is a useful table, showing the value of the measures of capacity in cubic inches, grains, and as compared with apothecaries' measure.

	Cubic inches.	Grains of distilled water.	Apothecaries' measure.
Imperial gallon, . .	277·274	70000	9·966 +
Imperial pint, . .	34·65925	8750	
Imperial fluidounce, .	1·7329625	437·5	
The old wine pint, .	28·8827	7291·666	16 fl. oz.
Old fluidounce, . .	1·805169	455·73	8 drachms.
Cubic inch, . .	1·	252·458	
Litre, ...	61·02525	15406·312	2·1135 pints.
Decilitre, . . .	6·10252	1540·631	3·3816 fl. oz.
Centilitre, . . .	0·61025	154·063	2·7053 fl. drachms.
Millilitre, . . .	0·06102	15·406	16·2318 minims.

Pipettes.—These are tubes for measuring liquids in drops, and consist wholly of glass, blown after either of the forms shown by Figs. 106, 109. The lower and capillary end of the pipette being placed in the liquid, is to be closed at the upper end by the thumb, as soon as the liquid in the bore has reached the level of that in the containing vessel. It is next brought immediately over the receiving vessel in which it is to be wholly or partly emptied, when the thumb is alternately raised and lowered until a sufficient number of drops has been forced out by atmospheric pressure to make up the volume or weight required, as the case may be. If the bore is too large, the liquid will run out in a thin stream, instead of drops. As the liquid rises in the bore of the pipette in proportion to the pressure of the external liquid, the deeper it is plunged into the containing vessel the greater the amount it will draw up.

Fig. 106.

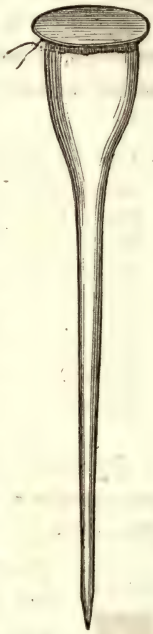
Fig. 107.

The flow of the liquid is completely under the control of the operator, it being only necessary to press down the thumb upon the mouth, to stop, completely, the dropping from the lower end. The above patterns are designed for very small operations. To be convenient for large quantities of li-

quid, they should be blown from a tube ten inches long, and with an inch bulb above the centre, as shown by Fig. 108, so as to form a reservoir.

Fig. 108.

Fig. 109.



This pipette may be filled by applying the mouth to the upper end, and sucking in the liquid; but the method is disagreeable to the operator when acid or other noxious fumes are natural to the liquid, and moreover it introduces moisture. The better plan, in such cases, is to make the pipette by drawing out the lower end of a tube to a capillary opening, and widening the upper, and then stretching a piece of india-rubber cloth tightly over the top, as shown by Fig. 109; or, more easily still, covering the bulb-pipette, at its top, with a caoutchouc ball. By compressing the bottle with the hand, or pressing against the india-rubber cover with the thumb, the air within the implement is partially forced out, and the liquid into which the pipettes are plunged immediately runs in to fill its place. The india-rubber having then regained its original state of distension by means of the upward pressure of the atmosphere, retains the liquid so completely that not a drop drains off until expelled by again pressing the bag or cover.

Fig. 110.

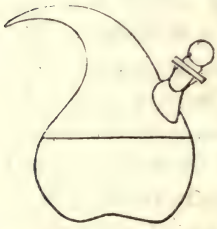


Fig. 111.

Another form of implement for measuring drops of liquid is Schuster's alkalimeter, shown by Fig. 110. It is a glass bottle, of 1 oz. capacity, with a ground stopper, from which the liquid issues dropwise, when the admission of air is properly adjusted by means of the stopper, which should, for that purpose, be held loosely in its place, and not lifted entirely out.

Graduated pipettes are also used for dropping definite quantities, with great precision. One, with caoutchouc cover, is very intelligibly represented by Fig. 111. Another form, and that which is much used in volumetric analysis, is shown by Fig. 112. It is known as Mohr's Dropping-tube, and consists of a glass tube drawn out to a capillary opening at the lower end, and graduated into 100° or divisions. To the capillary orifice a short piece of vulcanized india-rubber tubing is attached, and in the lower end of this, again, is inserted a short conical piece of glass tubing, which forms the spout through which the liquid is to flow. Clasping the india-rubber neck is a bent wire, which so compresses it as to make a water-tight joint; when, however, the grasp is relaxed by pressing the projecting ends of the wires between the thumb and fingers, the liquid flows through the neck dropwise, in slow or quick succession, according as the pressure is gentle or strong, the flow being controlled by this means.

Fig. 112.

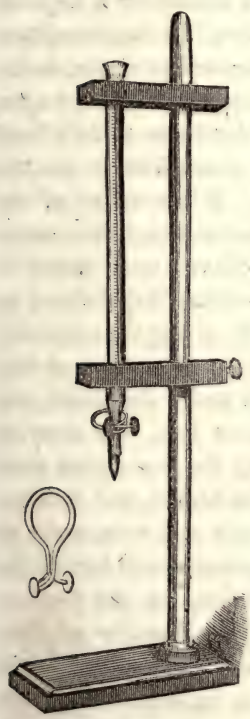


Fig. 113.

Some chemists prefer to use syringes for measuring liquids in drops, and these instruments are of glass, and as presented by Fig. 113. The liquid is drawn into them by immersing the lower end in the containing vessel and raising the piston. On pressing the top of the piston with the thumb, the liquid is driven out again, in quantity proportional to the force employed, a gentle depression expelling it dropwise and slowly. The stratum of air between the piston and surface of the liquid, as represented in the drawing, assists the action.

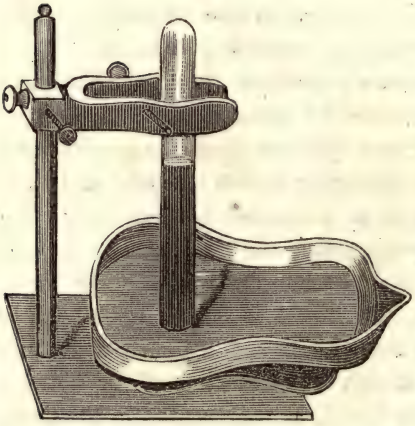
When the barrel of the syringe is graduated, like that shown in the figure which exhibits Alsop's minimeter, it allows the

transfer of a given quantity of liquid from one vessel to another at a single operation. To this end, it is only necessary to adjust the motion of the piston, so as to exactly draw in the required measure; and if an excess should be accidentally taken up, to gently depress the piston until it is expelled and the barrel is filled only to the proper degree or division.

Fig. 114.

MEASUREMENT OF GASES.*—In measuring a required volume of any gas, a graduated tube, like the one shown in Fig. 114, is first filled with mercury or water, as the case may be, in the pneumatic trough, and placed upon the shelf. When the tube is too slender to sustain itself in an upright position, it is then convenient to use the clamp and support A, Fig. 115. If the mouth of the receptacle of the gas is wide, it is necessary, before transferring to the graduating tube, to place a small funnel in its submerged end, so that the ascending bubbles may be received upon a larger surface. By giving the reservoir, generally a bell glass, a slightly inclined position, so that the edge of its mouth may reach under the funnel, the transfer is made easily and without loss. As soon as the requisite quantity has been transferred, the connection must be broken, and both the bell and tube made to resume their former positions on the shelf.—(See *Transfer of Gases.*) The tube is then to be depressed in the trough until the metal, inside and outside, is at the same level. This mode subjects the gas only to atmospheric pressure, but the tube must be held by a cork-lined clamp, as in Fig.

Fig. 115.



* See Regnault's Chemistry, and article EUDIOMETER in *Handwörterbuch der Chemie.* The latter explains the details of Bunsen's method for graduating tubes and measuring gases.

115, or linen holder, and not in the naked hand, the warmth of which, by expanding the gas, would be a source of error.

It is very difficult to transfer a quantity of gas exactly corresponding with a division of the tube at one trial—several attempts are requisite, except in cases of consummate manipulation. It is perhaps better to transfer the last portions from a small tube. The gas passing through very slowly and in fine bubbles can, by this arrangement, be stopped off as soon as the volume which has entered accords with the division indicated. When more than sufficient has been transferred, place the first finger upon the mouth of the tube so as to leave a partial opening, and incline it sufficiently to allow the exit of the redundant gas. Examine anew the contained volume, and if it is still in excess, repeat this operation until the level of the liquid reaches the proper height.

To insure accuracy in the comparison of volumes of different gases, they must necessarily be measured at the same temperature and under the same pressure. The proof-glasses in which they are estimated, should be kept out of the influence of unequal warmth during the process, for the action of heat upon the volume of gases is a cause of considerable error.

In order to determine with precision the exact height which the water or mercury assumes, the vessel should be placed at repose upon a level shelf, and the eye directed on a line with the surface of the fluids, and the height read off accordingly. This notation requires some care and precision, for as mercury assumes a convex surface, owing to its own cohesion, and water a concave one, because of the attraction for the walls of the tube, especially in narrow cylinders, the curve thus occasioned presents an impediment to the ready determination of the exact level. To provide against the action of the heat of the body, it is better to read at a distance of several yards, through a spy-glass.

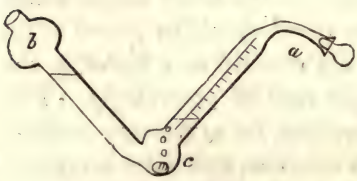
When water is the confining fluid, read the real surface in the middle of the dark zone formed by the water around the inner walls of the tube; on the other hand, when mercury is used, "place the real surface in a line drawn exactly in the centre between the highest point of the surface of the mercury and the points at which the latter is in actual contact with the walls of the tube."

In either case the temperature of the fluid and gas should be

uniform. When the bulk of the containing fluid is sufficient to allow the entire immersion of the cylinder, this is easily effected; otherwise, it becomes necessary to equalize the temperature of the surrounding air, by keeping the cylinder exposed to both, in order to determine accurately the degree of the scale at which the mercury or water stands.

Another important matter, as before mentioned, in the comparison of volumes of different gases, is the necessity of uniform pressure, in their measurement. If the level of the containing fluid within and without the cylinder exactly corresponds, the pressure upon it is directly shown by the barometer. A higher level, internally, indicates less pressure, and *vice versâ:* when the fluid stands higher outside of the cylinder than within it, the level may be restored by raising the tube; in the opposite case, by depressing the tube. These operations of adjusting the level are more difficult when mercury is the containing fluid. In operations occupying much time, the barometer should be frequently consulted, so as to guard against any alteration sufficient to impair the results.

Fig. 116.



Ker's tube, constructed for the measurement of gas at the time of its disengagement, is shown by Fig. 116. The branch *a*, ten inches in length, glass stoppered and graduated to two cubic inches, is the recipient of the gas disengaged from the material in the bulb *c*, by the action of a reagent introduced in the other branch *b*. The gas collecting in *a* is there measured by the scale, previous to being transferred for examination.

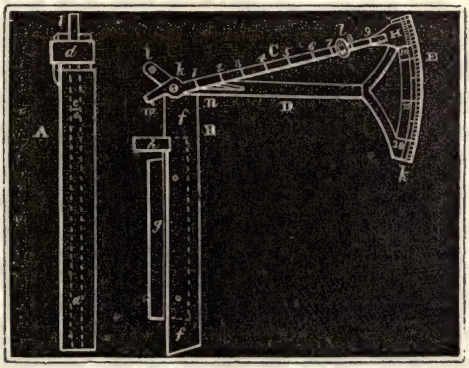
CHAPTER X.

MEASUREMENT OF TEMPERATURE.

TEMPERATURE is estimated by means of two instruments, the *pyrometer* and *thermometer*, the action of which is based upon the relative expansibility of bodies under the influence of heat and cold. They do not therefore indicate the amount of heat contained in the body, but only the comparative temperature of two or more bodies.

The Pyrometer.—This instrument is rarely used in the ordinary operations of the laboratory, it being only applicable to the measurement of heats more intense than can be borne by thermometers. Pyrometers are constructed of solid substances, though gaseous bodies, on account of their sensitiveness to heat or cold and greater uniformity of expansion, would be preferable. Wedgwood's Pyrometer is the oldest invention, but Daniell's instrument is the most approved, and by skilful management may be made to give accurate indications. Its principal application is in furnace operations. In assaying, where the required temperature varies with the metal under process, it is particularly avail-

Fig. 117.



able in determining the heat of the furnace; for much of the accuracy of the assay depends upon the temperature at which it is made. Fig. 117 represents the apparatus.

"It consists of two parts, which may be distinguished as the register 1, and the scale 2. The register A, is a solid bar of blacklead earthenware highly baked. In this a hole *a a*, is drilled, into which a bar of any metal, six inches long, may be dropped, and which will then rest upon its solid end. A cylindrical piece of porcelain *c*, called the index, is then placed upon the top of the bar, and confined in its place by a ring or strap of platinum *d*, passing round the top of the register, which is partly cut away at the top, and tightened by a wedge of porcelain *e*. When such an arrangement is exposed to high temperature, it is obvious that the expansion of the metallic bar will force the index forward to the amount of the excess of its expansion over that of the blacklead, and that when again cooled it will be left at the point of greatest elongation. What is now required, is the measurement of the distance which the index has been thrust forward from its first position, and this, though in any case but small, may be effected with great precision by means of the scale."

"This is independent of the register, and consists of two rules of brass, *f f* and *g*, accurately joined together at a right angle by their edges, and fitting square upon the two sides of the blacklead bar. At one end of this double rule, a small plate of brass *h*, projects at a right angle, which may be brought down upon the shoulder of the register formed by the notch cut away for the reception of the index. A movable arm D is attached to this frame, turning at its fixed extremity on a centre *i*, and at its other carrying the arc of a circle, whose radius is exactly five inches, accurately divided into degrees, and thirds of a degree. Upon this arm, at the centre of the circle *k*, another lighter arm C, is made to turn, one end of which carries a nonius H with it, which moves upon the face of the arc, and subdivides the former graduation into minutes of a degree; the other end crosses the centre and terminates in an obtuse steel point *m*, turned inwards at a right angle.

"When an observation is to be made, a bar of platinum or malleable iron is placed in the cavity of the register; the index is to be pressed down upon it, and firmly fixed in its place by the platinum strap and porcelain wedge. The scale is then to be applied by carefully adjusting the brass rule to the sides of the

register, and fixing it by pressing the cross-piece upon the shoulder, and placing the movable arm so that the steel part of the radius may drop into a small cavity made for its reception, and coinciding with the axis of the metallic bar. The minute of the degree must then be noted which the nonius indicates upon the arc. A similar observation must be made after the register has been exposed to the increased temperature which it is designed to measure, and again cooled, and it will be found that the nonius has been moved forward a certain number of degrees or minutes. The scale of this pyrometer is readily connected with that of the thermometer by immersing the register in boiling mercury, whose temperature is as constant as that of boiling water, and has been accurately determined by the thermometer. The amount of expansion for a known number of degrees is thus determined, and the value of all other expansions may be considered as proportionate."

"The following is a list of the melting-points of some of the metals, and it is obvious that in an assay of each particular metal, the temperature employed must exceed by a considerable number of degrees its melting-point. The table is, therefore, very useful.

	Fahrenheit.
Tin melts at	422°
Bismuth,	497
Lead,	612
Zinc,	773
Cadmium,	442
Silver,	1860
Copper,	1996
Gold,	2016
Cast iron,	2786

Cobalt and nickel rather less fusible than iron."

Daniell.

Thermometers.—A thermometer consists of a graduated cylindrical stem, with a uniform capillary bore, having one of its ends blown into a bulb and filled with mercury or alcohol, and the other hermetically closed, the space above the column of fluid being a vacuum, or as nearly as possible devoid of air.

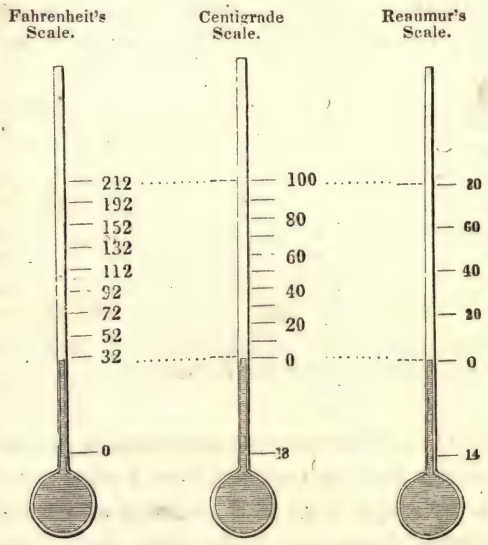
Mercury, on account of its greater equability of expansion, and of its boiling-point being as high as 650° F., is more available in the construction of thermometers for measuring tempera-

tures exceeding that of boiling water (212° F.) Alcohol, on the other hand, by reason of its eminent property of dilatation is more applicable for determining temperatures lower than the freezing-point of mercury, its point of congelation being as far down as —90° F.

The two points of graduation are the freezing and boiling points of water, the interval between each being differently apportioned, according as the scale of Fahrenheit, Celsius, or Reaumur (the three most in use) is employed.

Fahrenheit's scale ranges from 32° to 212°; that of Celsius (centigrade) from 0° to 100°; Reaumur's from 0° to 80°. The first is most popular in England and in this country; the second in France, and the third in Russia, Spain, and part of Germany. The scale of Fahrenheit has its zero at 32° below the freezing-point of water, and the other two exactly at that point. Therefore, in comparing the degrees of the former with those of the

Fig. 118.



latter, the negative or those below zero have a prefix of the minus (—) sign, and the positive or those above, the plus (+)

sign. The diagram (Fig. 118) will present the relative position of the corresponding degrees of the three scales.

The following rules will be found convenient for translating the degrees of one scale into those of another:

1. To reduce Centigrade degrees to those of Fahrenheit, multiply by 9, and divide by 5, and to the quotient add 32, that is,—

$$\frac{\text{Cent.} \times 9}{5} + 32 = \text{Fahr.}$$

2. To reduce Fahrenheit's degrees to Centigrade:

$$\frac{\text{Fahr.} - 32 \times 5}{9} = \text{Cent.}$$

3. To reduce Reaumur's to Fahrenheit's:—

$$\frac{\text{Reau.} \times 9}{4} + 32 = \text{Fahr.}$$

4. To convert Fahrenheit's to Reaumur's:—

$$\frac{\text{Fahr.} - 32 \times 4}{9} = \text{Reaumur.}$$

A slender stem and precise uniformity of bore are indispensable to the accuracy of a thermometer. The tube must also be entirely void of air, as is known when, on being inverted, the contained mercury makes a free and rapid descent. Moreover, the graduation of the scale must be verified, and to do this, the bulb is immersed in a mixture of salt and snow to test the accuracy of its freezing degree, and afterwards in boiling water (under the ordinary pressure of the atmosphere) to observe its boiling-point. If in either case when the fluid becomes stationary, after sufficient delay for the bulb to accquire the temperature of the bath, it corresponds with the degree marked upon the scale, its graduation as regards the freezing and boiling points is correct. To determine the exactness of the intermediate space, the length of the interval is measured with a pair of compasses, and it is then easy to ascertain by means of an accurate ruler, if the divisions accord with each other, and in the aggregate with the total length of the scale.

For measuring temperatures higher than 580° F., the top of the thermometer should be unsealed and the mercury exposed to

Fig. 119.

the pressure of the atmosphere, for if hermetically closed, it will boil at that point and burst the tube.

The tube, as before said, should be as slender as possible, and not too long, otherwise in testing shallow solutions in ebullition, that part of the stem which is above the liquor is exposed to the heat of the rising vapor, and as the expansion to mercury within would be thus estimated with that of the contents of the bulb, the only part heated at the time of graduation, incorrect conclusions would be drawn.

In ascertaining the condition of a liquid with regard to heat or cold, the thermometer is gradually introduced into it, moved around it several times so as to produce an equable diffusion of temperature, and after the mercury has become stationary at a certain point, the degree coincident with that point is noted down as the temperature.

The scales of thermometers are most generally graduated upon a wooden slip or support, to which the stem is secured by clamps and screws. In such case, the scale is hinged, so as to afford convenience in the use of the thermometer for taking the boiling-point of solutions without injury to the scale.

Thermometers for chemical purposes should be wholly of glass and cylindrical, as that form is most convenient for passing through tubulures; and, moreover, the scales should be

Fig. 120.

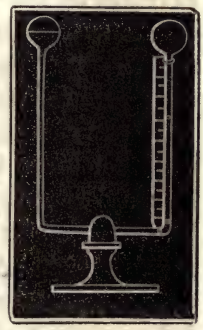
indestructible. The annexed drawings present one (Fig. 119) with Celsius's scale etched on the outside by fluorine, and another (Fig. 120) with a black letter enamelled, Fahrenheit, scale enclosed in the tube.

The scales of the mercurial thermometers are made to range as high as 600° F., and for convenience are sometimes graduated on one side of the stem with the Centigrade and on the other with the Fahrenheit scale. Fahrenheit's degrees being small, have the advantage over the others of not giving fractional parts, which are inconvenient in calculation. The laboratory should be supplied with two or more of these implements.

Air thermometers are sometimes used, and though very delicate, are less convenient than those of mercury and alcohol, and liable to objections which do not attach to the latter.

Leslie's differential thermometer, Fig. 121, which is a modification of the air thermometer, is now frequently used in researches for determining very small differences in temperature. It consists of a U tube with a hollow bulb blown at each end and closed, so that the fluid within (sulphuric acid) colored with carmine to render it more visible, is entirely free from external atmospheric pressure. This instrument does not exhibit a change of temperature except by the difference between the elasticity of the air in the two bulbs, and therefore indicates only such temperatures as affect one bulb and not the other. When both bulbs are of equal temperature, the liquid within remains stationary; but so soon as one becomes warmer than the other the fluid recedes to the opposite bulb, and the scale attached to one of the legs is so graduated as to measure the comparative degree of heat thus occasioned.

Fig. 121.

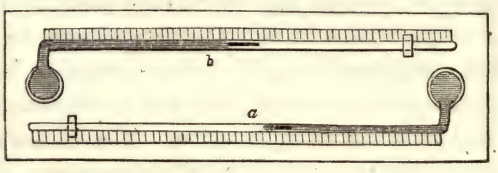


Melloni's thermo-multiplicator (Müller, p. 541), is another instrument for the indication of changes of temperature.

Another convenient instrument, especially in meteorological observations, is the *thermometrograph*. It is so constructed as to register the maximum and minimum temperatures occurring during an interval, and hence the presence of the operator is not necessary to note them at the moment of their occurrence.

The apparatus which is shown in Fig. 122, consists of a mercurial and a spirit thermometer placed horizontally and parallel to each other. A steel pin enclosed in the tube of the former is pushed before the column of mercury when the metal in the bulb

Fig. 122.



expands, but remains fixed when it again recedes on cooling, and thus indicates at that point the maximum temperature which has occurred during any interval.

The corresponding rod, enclosed in the tube of the spirit thermometer, of glass, colored to render it more visible, is not advanced by the expansion of the spirit, but retreats with the column as it contracts to the last point reached by it, and thus registers the minimum of temperature during a certain time, at the degree coincident with its inner end.

When this instrument is to be used, it must be inclined in such a position as to allow the steel rod to descend to the column of mercury, and the glass rod to the end of the spirituous column. The arrangement of the bulbs in opposite positions is with a view to this object. After the rods have reached their proper situations, we may, by placing the instrument horizontally any morning or evening, obtain at the end of the following 24 hours, the maximum and minimum temperature of that interval.

There are some very excellent remarks by Regnault upon the relative advantages of the different modes of measuring temperature, to which the student may advantageously refer.

The translation of his several papers on the subject, is to be found in the Franklin Institute Journal for 1848.

The following table shows the corresponding degrees of Fahrenheit's, Reaumur's, and the Centigrade thermometers.

Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.
600	252·4	315·5	569	238·6	298·3	539	225·3	281·6	508	211·5	264·4
599	252	315	568·4	238·4	298	538·2	225	281·2	507·2	211·2	264
598	251·5	314·4	568	238·2	297·7	538	224·9	281·1	507	211·1	263·8
567·2	251·2	314	567·5	238	297·5	537·8	224·8	281	506·7	211	263·7
597	251·1	313·8	567	237·7	297·2	537	224·4	280·5	506	210·6	263·3
596·7	251	313·7	566·6	237·6	297	536	224	280	505·4	210·4	263
596	250·3	313·3	566	237·3	296·6	535	223·5	279·4	505	210·2	262·7
595·4	250·4	313	565·2	237	296·2	534·2	223·2	279	504·5	210	262·5
595	250·2	312·7	565	236·9	296·1	534	223·1	278·8	504	209·7	262·2
594·5	250	312·5	564·8	236·8	296	533·7	223	278·7	503·6	209·6	262
594	249·7	312·2	564	236·4	295·5	533	222·6	278·3	503	209·3	261·6
593·6	249·6	312	563	236	295	532·4	222·4	278	502·2	209	261·2
593	249·3	311·6	562	235·5	294·4	532	222·2	277·7	502	208·9	261·1
592·2	249	311·2	561·2	235·2	294	531·5	222	277·5	501·8	208·8	261
592	248·9	311·1	561	235·1	293·8	531	221·7	277·2	501	208·4	260·5
591·8	248·8	311	560·7	235	293·7	530·6	221·6	277	500	208	260
591	248·4	310·5	560	234·6	293·3	530	221·3	276·6	499	207·5	259·4
590	248	310	559·4	234·4	293	529·2	221	276·2	498·2	207·2	259
589	247·5	309·4	559	234·2	292·7	529	220·9	276·1	498	207·1	258·8
588·2	247·2	309	558·5	234	292·5	528·8	220·8	276	497·7	207	258·7
588	247·1	308·8	558	233·7	292·2	528	220·4	275·5	497	206·6	258·3
587·7	247	308·7	557·6	233·6	292	527	220	275	496·4	206·4	258
587	246·6	308·3	557	233·3	291·6	526	219·5	274·4	496	206·2	257·7
586·4	246·4	308	556·2	233	291·2	525·2	219·2	274	495·5	206	257·5
586	246·2	307·7	556	232·9	291·1	525	219·1	273·8	495	205·7	257·2
585·5	246	307·5	555·8	232·8	291	524·7	219	273·7	494·6	205·6	257
585	245·7	307·2	555	232·4	290·5	524	218·6	273·3	494	205·3	256·6
584·6	245·6	307	554	232	290	523·4	218·4	273	493·2	205	256·2
584	245·3	306·6	553	231·5	289·4	523	218·2	272·7	493	204·9	256·1
583·2	245	306·2	552·2	231·2	289	522·5	218	272·5	492·8	204·8	256
583	244·9	306·1	552	231·1	288·8	522	217·7	272·2	492	204·4	255·5
582·8	244·8	306	551·7	231	288·7	521·6	217·6	272	491	204	255
582	244·4	305·5	551	230·6	288·3	521	217·3	271·6	490	203·5	254·4
581	244	305	550·4	230·4	288	520·2	217	271·2	489·2	203·2	254
580	243·5	304·4	550	230·2	287·7	520	216·9	271·1	489	203·1	253·8
579·2	243·2	304	549·5	230	287·5	519·8	216·8	271	488·7	203	253·7
579	243·1	303·8	549	229·7	287·2	519	216·4	270·5	488	202·6	253·3
578·7	243	303·7	548·6	229·6	287	518	216	270	487·4	202·4	253
578	242·6	303·3	548	229·3	286·6	517	215·5	269·4	487	202·2	252·7
577·4	242·4	303	547·2	229	286·2	516·2	215·2	269	486·5	202	252·5
577	242·2	302·7	547	228·9	286·1	516	215·1	268·8	486	201·7	252·2
576·5	242	302·5	546·8	228·8	286	515·7	215	268·7	485·6	201·6	252
576	241·7	302·2	546	228·4	285·5	515	214·6	268·3	485	201·3	251·6
575·6	241·6	302	545	228	285	514·4	214·4	268	484·2	201	251·2
575	241·3	301·6	544	227·5	284·4	514	214·2	267·7	484	200·9	251·1
574·2	241	301·2	543·2	227·2	284	513·5	214	267·5	483·8	200·8	251
574	240·9	301·1	543	227·1	283·8	513	213·7	267·2	483	200·4	250·5
573·8	240·8	301	542·7	227	283·7	512·6	213·6	267	482	200	250
573	240·4	300·5	542	226·6	283·3	512	213·3	266·6	481	199·5	249·4
572	240	300	541·4	226·4	283	511·2	213	266·2	480·2	199·2	249
571	239·5	299·4	541	226·2	282·7	511	212·9	266·1	480	199·1	248·8
570·2	239·2	299	540·5	226	282·5	510·8	212·8	266	479·7	199	248·7
570	239·1	298·8	540	225·7	282·2	510	212·4	265·5	479	198·6	248·3
569·7	239	298·7	539·6	225·6	282	509	212	265	478·4	198·4	248

Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.
478	198·2	247·7	448·2	185	231·2	418	171·5	214·4	388·4	158·4	198
477·5	198	247·5	448	184·9	231·1	417·2	171·2	214	388	158·2	197·7
477	197·7	247·2	447·8	184·8	231	417	171·1	213·8	387·5	158	197·5
476·6	197·6	247	447	184·4	230·5	416·7	171	213·7	387	157·7	197·2
476	197·3	246·6	446	184	230	416	170·6	213·3	386·6	157·6	197
475·2	197	246·2	445	183·5	229·4	415·4	170·4	213	386	157·3	196·6
475	196 9	246·1	444·2	183·2	229	415	170·2	212·7	385·2	157	196·2
474·8	196·8	246	444	183·1	228·8	414·5	170	212·5	385	156·9	196·1
474	196·4	245·5	443·7	183	228·7	414	169·7	212·2	384·8	156·8	196
473	196	245	443	182·6	228·3	413·6	169·6	212	384	156·4	195·5
472	195·5	244·4	442·4	182·4	228	413	169·3	211·6	383	156	195
471·2	195·2	244	442	182·2	227·7	412·2	169	211·2	382	155·5	194·4
471	195·1	243·8	441·5	182	227·5	412	168·9	211·1	381·2	155·2	194
470·7	195	243·7	441	181·7	227·2	411·8	168·8	211	381	155·1	193·8
470	194·6	243·3	440·6	181·6	227	411	168·4	210·5	380·7	155	193·7
469·4	194·4	243	440	181·3	226·6	410	168	210	380	154·6	193·3
469	194·2	242·7	439·2	181	226 2	409	167·5	209·4	379·4	154·4	193
468·5	194	242·5	439	180·9	226·1	408·2	167·2	209	379	154·2	192·7
468	193·7	242·2	438·8	180·8	226	408	167·1	208·8	378·5	154	192·5
467·6	193·6	242	438	180·4	225·5	407·7	167	208·7	378	153·7	192·2
467	193·3	241·6	437	180	225	407	166·6	208·3	377·6	153·6	192
466·2	193	241·2	436	179·5	224·4	406·4	166·4	208	377	153·3	191·6
466	192·9	241·1	435·2	179 2	224	406	166·2	207·7	376·2	153	191·2
465·8	192·8	241	435	179·1	223·8	405·5	166	207·5	376	152·9	191·1
465	192·4	240·5	434·7	179	223·7	405	165 7	207 2	375·8	152·8	191
464	192	240	434	178·6	223·3	404·6	165·6	207	375	152·4	190·5
463	191·5	239·4	433·4	178·4	223	404	165·3	206·6	374	152	190
462·2	191·2	239	433	178·2	222·7	403·2	165	206 2	373	151 5	189·4
462	191·1	238·8	432·5	178	222·5	403	164·9	206·1	372·2	151·2	189
461·7	191	238·7	432	177·7	222·2	402·8	164·8	206	372	151·1	188·8
461	190·6	238 3	431·6	177·6	222	402	164·4	205·5	371·7	151	188·7
460·4	190·4	238	431	177·3	221·6	401	164	205	371	150·6	188·3
460	190·2	237·7	430·2	177	221·2	400	163·5	204·4	370·4	150·4	188
459·5	190	237·5	430	176 9	221·1	399·2	163·2	204	370	150·2	187·7
459	189·7	237·2	429·8	176 8	221	399	163·1	203·8	369 5	150	187·5
458·6	189·6	237	429	176·4	220·5	398·7	163	203 7	369	149 7	187·2
458	189·3	236·6	428	176	220	398	162·6	203 3	368·6	149·6	187
457·2	189	236 2	427	175 5	219·4	397·4	162·4	203	368	149·3	186·6
457	188·9	236·1	426·2	175·2	219	397	162·2	202·7	367·2	149	186·2
456·8	188·8	236	426	175·1	218·8	396·5	162	202·5	367	148·9	186·1
456	188·4	235·5	425 7	175	218·7	396	161·7	202·2	366 8	148·8	186
455	188	235	425	174·6	218·3	395·6	161 6	202	366	148·4	185·5
454	187·5	234·4	424·4	174·4	218	395	161 3	201·6	365	148	185
453·2	187·2	234	424	174·2	217·7	394·2	161	201·2	364	147·5	184·4
453	187·1	233·8	423·5	174	217·5	394	160·9	201·1	363·2	147·2	184
452·7	187	233·7	423	173·7	217·2	393·8	160·8	201	363	147·1	183·8
452	186·6	233·3	422·6	173 6	217	393	160 4	200 5	362·7	147	183·7
451·4	186·4	233	422	173·3	216 6	392	160	200	362	146·6	183·3
451	186·2	232·7	421·2	173	216·2	391	159·5	199·4	361·4	146·4	183
450·5	186	232·5	421	172·9	216·1	390·2	159·2	199	361	146·2	182·7
450	185·7	232·2	420·8	172·8	216	390	159·1	198·8	360·5	146	182·5
449·6	185·6	232	420	172·4	215·5	389·7	159	198·7	360	145 7	182·2
449	185·3	231·6	419	172	215	389	158 6	198·3	359·6	145·6	182

Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.
359	145 3	181·6	329	132	165	299	118·6	148·3	269·6	105·6	132
358·2	145	181·2	328	131·5	164·4	298·4	118·4	148	269	105·3	131·6
358	144·9	181·1	327·2	131·2	164	298	118·2	147·7	268·2	105	131·2
357 8	144·8	181	327	131·1	163·9	297·5	118	147·5	268	104·8	131·1
357	144·4	180·5	326·7	131	163·7	297	117·7	147·2	267·8	104·8	131
356	144	180	326	130·6	163·3	296 6	117·6	147	267	104·4	130·5
355	143·5	179·4	325·4	130·4	163	296	117·3	146 6	266	104	130
354·2	143·2	179	325	130·2	162·7	295·2	117	146·2	265	103 5	129·4
354	143·1	178·8	324·5	130	162·5	295	116 9	146·1	264·2	103 2	129
353·7	143	178 7	324	129·7	162·2	294 8	116·8	146	264	103·1	128·9
353	142·6	178·3	323·6	129·6	162	294	116·4	145·5	263·7	103	128·7
352·4	142·4	178	323	129·3	161·6	293	116	145	263	102·6	128 3
352	142·2	177·7	322·2	129	161·2	292	115·5	144·4	262·4	102·4	128
351·5	142	177·5	322	128 8	161·1	291·2	115·2	144	262	102·2	127·7
351	141·8	177·2	321·8	128 8	161	291	115·1	143·8	261·5	102	127 5
350·6	141·6	177	321	128·4	160·5	290·7	115	143·7	261	101·7	127·2
350	141·3	176·6	320	128	160	290	114 6	143·3	260·6	101·6	127
349·2	141	176·2	319	127·5	159·4	289·4	114 4	143	260	101·3	126·6
349	140·9	176·1	318·2	127·2	159	289	114 2	142 7	259·2	101	126·2
348·8	140·8	176	318	127·1	158·8	288·5	114	142·5	259	100·8	126·1
348	140 4	175·5	317·7	127	158·7	288	113·7	142 2	258·8	100·8	126
347	140	175	317	126·6	158 3	287·6	113·6	142	258	100·4	125·5
346	139·5	174·4	316·4	126·4	158	287	113·3	141·6	257	100	125
345·2	139 2	174	316	126 2	157·7	286·2	113	141·2	256	99·5	124·4
345	139·1	173·8	315·5	126	157·5	286	112 8	141·1	255·2	99·2	124
344·7	139	173·7	315	125·7	157·2	285·8	112·8	141	255	99·1	123 8
344	138·6	173·3	314·6	125·6	157	285	112·4	140 5	254·7	99	123·7
343 4	138 4	173	314	125·3	156·6	284	112	140	254	98·6	123·3
343	138 2	172·7	313 2	125	156·2	283	111·5	139·4	253 4	98·4	123
342·5	138	172·5	313	124 8	156·1	282·2	111·2	139	253	98·2	122·7
342	137·7	172 2	312·8	124·8	156	282	111·1	138 9	252·5	98	122·5
341·6	137·6	172	312	124·5	155·5	281·7	111	138·7	252	97·9	122·2
341	137·3	171·6	311	124	155	281	110·6	138 3	251·6	97·6	122
340·2	137	171·2	310	123·5	154 4	280·4	110·4	138	251	97·3	121·6
340	136·9	171·1	309·2	123·2	154	280	110·2	137·7	250·2	97	121 2
339·8	136 8	171	309	123·1	153 8	279·5	110	137·5	250	96·9	121·1
339	136·4	170·5	308·7	123	153 7	279	109·7	137·2	249·8	96·8	121
338	136	170	308	122·6	153·3	278·6	109·6	137	249	96·4	120·5
337	135 5	169·4	307·4	122·4	153	278	109·3	136·6	248	96	120
336·2	135·2	169	307	122·2	152·7	277·2	109	136·2	247	95 5	119·4
336	135·1	168·8	306·5	122	152·5	277	108·8	136·1	246·2	95·2	119
335·7	135	168·7	306	121·7	152·2	276·8	108·8	136	246	95 1	118·9
335	134·6	168 3	305·6	121 6	152	276	108·4	135·5	245 7	95	118·7
334·4	134·4	168	305	121·3	151·6	275	108	135	245	94·6	118·3
334	134·2	167·7	304·2	121	151 2	274	107·5	134·4	244·4	94·4	118
333·5	134	167·5	304	120·9	151·1	273 2	107·2	134	244	94·2	117·8
333	133·7	167·2	303 8	120 8	151	273	107 1	133 8	243·5	94	117·5
332·6	133·6	167	303	120·4	150·5	272·7	107	133·7	243	93 8	117·2
332	133·3	166·6	302	120	150	272	106·6	133 3	242 6	93 6	117
331·2	133	166·2	301	119·5	149·4	271·4	106·4	133	242	93·3	116 6
331	132 9	166·1	300·2	119·2	149	271	106 2	132·7	241·2	93	116 2
330·8	132·8	166	300	119·1	148·9	270 5	106	132 5	241	92·9	116 1
330	132·4	165·5	299·7	119	148·7	270	105 7	132·2	240·8	92·8	116

Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.
240	92·4	115·5	209·7	79	98 7	180	65·7	82·2	150 8	52·8	66
239	92	115	209	78·6	98 3	179·6	65·6	82	150	52·4	65·5
238	91·5	114·4	208·4	78·4	98·0	179	65 3	81·6	149	52	65
237·2	91·2	114	208	78·2	97·8	178·2	65	81·2	148	51·5	64·4
237	91·1	113·9	207·5	78	97 5	178	64·9	81·1	147·2	51·2	64
236·7	91	113·7	207	77·7	97·2	177·8	64·8	81	147	51·1	63·9
236	90 3	113·3	206·6	77·6	97	177	64·4	80 5	146·7	51	63·7
235·4	90·4	113	206	77·3	96·6	176	64	80	146	50 6	63·3
235	90·2	112·7	205·2	77	96 2	175	63·5	79·4	145·4	50·4	63
234·5	90	112·5	205	76·9	96·1	174·2	63·2	79	145	50·2	62·7
234	89·7	112 2	204·8	76 8	96	174	63·1	78 8	144·5	50	62·5
233·6	89 6	112	204	76·4	95·5	173·7	63	78·7	144	49 7	62 2
233	89·3	111·6	203	76	95	173	62·6	78·3	143·6	49 6	62
232·2	89	111·2	202	75·5	94·4	172·4	62·4	78	143	49 3	61·6
232	88·9	111·1	201·2	75·2	94	172	62·2	77·7	142·2	49	61·2
231·8	88·8	111	201	75·1	93·9	171·5	62	77·5	142	48·9	61·1
231	88·4	110·5	200·7	75	93·7	171	61·7	77·2	141·8	48 8	61
230	88	110	200	74·6	93·3	170·6	61·6	77	141	48·4	60·5
229	87·5	109·4	199·4	74·4	93	170	61·3	76·6	140	48	60
228·2	87·2	109	199	74·2	92 7	169·2	61	76 2	139	47 5	59·4
228	87·1	108·9	198·5	74	92·5	169	60·8	76·1	138·2	47·2	59
227 7	87	108·7	198	73 7	92·2	168·8	60·8	76	138	47·1	58·8
227	86·6	108 3	197·6	73·6	92	168	60·4	75·5	137·7	47	58·7
226 4	86·4	108	197	73·3	91 6	167	60	75	137	46·6	58·3
226	86·2	107·8	196·2	73	91·2	166	59·5	74·4	136·4	46·4	58
225·5	86	107·5	196	72·8	91·1	165·2	59·2	74	136	46·2	57·7
225	85·7	107·2	195·8	72·8	91	165	59·1	73·9	135·5	46	57·5
224·6	85·6	107	195	72·4	90·5	164·7	59	73·7	135	45·8	57·2
224	85·3	106·6	194	72	90	164	58·6	73·3	134·6	45·6	57
223·2	85	106·2	193	71·5	89·4	163·4	58·4	73	134	45·3	56·6
223	84·9	106·1	192·2	71·2	89	163	58·2	72·7	133·2	45	56·2
222 8	84·8	106	192	71·1	88·8	162·5	58	72·5	133	44·9	56·1
222	84·4	105·5	191·7	71	88·7	162	57·7	72·2	132·8	44·8	56
221	84	105	191	70·6	88 3	161 6	57·6	72	132	44·5	55·5
220	83·5	104·4	190·4	70·4	88	161	57·3	71·6	131	44	55
219·2	83·2	104	190	70·2	87 8	160·2	57	71·2	130	43·5	54·4
219	83·1	103·9	189·5	70	87·5	160	56·8	71·1	129·2	43·2	54
218·7	83	103·7	189	69·7	87·2	159·8	56·8	71	129	43·1	53·9
218	82·6	103·3	188·6	69·6	87	159	56·4	70·5	128·7	43	53·7
217·4	82·4	103	188	69·3	86·6	158	56	70	128	42·6	53·3
217	82·2	102·7	187·2	69	86·2	157	55·5	69·4	127·4	42·4	53
216·5	82	102·5	187	68·9	86·1	156·2	55·2	69	127	42·2	52·7
216	81·7	102·2	186·8	68·8	86	156	55·1	68·9	126·5	42	52·5
215 6	81·6	102	186	68·4	85·5	155·7	55	68·7	126	41·8	52·2
215	81·3	101·6	185	68	85	155	54·6	68·3	125·6	41·6	52
214·2	81	101·2	184	67·5	84·4	154·4	54·4	68	125	41·3	51·6
214	80·9	101·1	183·2	67.2	84	154	54·2	67·7	124·2	41	51·2
213·8	80·8	101	183	67·1	83 9	153·5	54	67·5	124	40·9	51·1
213	80·4	100·5	182·7	67	83·7	153	53·7	67·2	123·8	40·8	51
212	80	100	182	66·6	83·3	152·6	53·6	67	123	40·4	50·5
211	79·5	99·4	181·4	66·4	83	152	53·3	66·6	122	40	50
210·2	79·2	99	181	66·2	82·7	151.2	53	66·2	121	39·5	49·4
210	79·1	98·9	180·5	66	82·5	151	52·9	66·1	120·2	39·2	49

Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.
120	39·1	48·9	90·5	26	32·5	61	12·9	16·1	30·2	—0·8	—1
119·7	39	48·7	90	25·7	32·2	60·8	12·8	16	30	—0·9	—1·1
119	38·6	48·3	89·6	25·6	32	60	12·4	15·5	29·7	—1	—1·2
118·4	38·4	48	89	25·3	31·6	59	12	15	29	—1·3	—1·6
118	38·2	47·7	88·2	25	31·2	58	11·5	14·4	28·4	—1·6	—2
117·5	38	47·5	88	24·9	31·1	57·2	11·2	14	28	—1·7	—2·2
117	37·7	47·2	87·8	24·8	31	57	11·1	13·8	27·5	—2	—2·5
116·6	37·6	47	87	24·4	30·5	56·7	11	13·7	27	—2·2	—2·7
116	37·3	46·6	86	24	30	56	10·6	13·3	26·6	—2·4	—3
115·2	37	46·2	85	23·5	29·4	55·4	10·4	13	26	—2·6	—3·3
115	36·9	46·1	84·2	23·2	29	55	10·2	12·7	25·2	—3	—3·7
114·8	36·8	46	84	23·1	28·9	54·5	10	12·5	25	—3·1	—3·8
114	36·4	45·5	83·7	23	28·7	54	9·7	12·2	24·8	—3·2	—4
113	36	45	83	22·6	28·3	53·6	9·6	12	24	—3·5	—4·4
112	35·5	44·4	82·4	22·4	28	53	9·3	11·6	23	—4	—5
111·2	35·2	44	82	22·2	27·7	52·2	9	11·2	22	—4·4	—5·5
111	35·1	43·9	81·5	22	27·5	52	8·9	11·1	21·2	—4·8	—6
110·7	35	43·7	81	21·7	27·2	51·8	8·8	11	21	—4·9	—6·1
110	34·6	43·3	80·6	21·6	27	51	8·4	10·5	20·7	—5	—6·2
109·4	34·4	43	80	21·3	26·6	50	8	10	20	—5·3	—6·6
109	34·2	42·7	79·2	21	26·2	49	7·5	9·4	19·4	—5·6	—7
108·5	34	42·5	79	20·9	26·1	48·2	7·2	9	19	—5·7	—7·2
108	33·8	42·2	78·8	20·8	26	48	7·1	8·9	18·5	—6	—7·5
107·6	33·6	42	78	20·4	25·5	47·7	7	8·7	18	—6·2	—7·7
107	33·3	41·6	77	20	25	47	6·6	8·3	17·6	—6·4	—8
106·2	33	41·2	76	19·5	24·4	46·4	6·4	8	17	—6·6	—8·3
106	32·9	41·1	75·2	19·2	24	46	6·2	7·7	16·2	—7	—8·7
105·8	32·8	41	75	19·1	23·8	45·5	6	7·5	16	—7·1	—8·9
105	32·4	40·5	74·7	19	23·7	45	5·7	7·2	15·8	—7·2	—9
104	32	40	74	18·6	23·3	44·6	5·7	7	15	—7·5	—9·4
103	31·5	39·4	73·4	18·4	23	44	5·3	6·6	14	—8	—10
102·2	31·2	39	73	18·2	22·7	43·2	5	6·2	13	—8·4	—10·5
102	31·1	38·9	72·5	18	22·5	43	4·9	6·1	12·2	—8·8	—11
101·7	31	38·7	72	17·7	22·2	42·8	4·8	6	12	—8.9	—11·1
101	30·6	38·3	71·6	17·6	22	42	4·4	5·5	11·7	—9	—11·2
100·4	30·4	38	71	17·3	21·6	41	4	5	11	—9·3	—11·6
100	30·2	37·7	70·2	17	21·2	40	3·5	4·4	10·4	—9·6	—12
99·5	30	37·5	70	16·9	21·1	39·2	3·2	4	10	—9·7	—12·2
99	29·7	37·2	69·8	16·8	21	39	3·1	3·9	9·5	—10	—12·5
98·6	29·6	37	69	16·4	20·5	38·7	3	3·7	9	—10·2	—12·7
98	29·3	36·6	68	16	20	38	2·6	3·3	8·6	—10·4	—13
97·2	29	36·2	67	15·5	19·4	37·4	2·4	3	8	—10·6	—13·3
97	28·9	36·1	66·2	15·2	19	37	2·2	2·7	7·2	—11	—13·7
96·8	28·8	36	66	15·1	18·8	36·5	2	2·5	7	—11·1	—13·9
96	28·4	35·5	65·7	15	18·7	36	1·7	2·2	6·8	—11·2	—14
95	28	35	65	14·6	18·3	35·6	1·6	2	6	—11·5	—14·4
94	27·5	34·4	64·4	14·4	18	35	1·3	1·6	5	—12	—15
93·2	27·2	34	64	14·2	17·7	34·2	1	1·2	4	—12·4	—15·5
93	27·1	33·9	63·5	14	17·5	34	0·9	1·1	3·2	—12·8	—16
92·7	27	33·7	63	13·7	17·2	33·8	0·8	1	3	—12·9	—16·1
92	26·6	33·3	62·6	13·6	17	33	0·4	0·5	2·7	—13	—16·2
91·4	26·4	33	62	13·3	16·6	32	0	0	2	—13·3	—16·6
91	26·2	32·7	61·2	13	16·2	31	—0·4	—0·5	1·4	—13·6	—17

Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.	Fahrenheit.	Reaumur.	Centigrade.
1	—13·7	—17·2	— 9·4	—18·4	—23	—20	—23·1	—28·9	—30	—27·5	—34·4
0·5	—14	—17·5	—10	—18·6	—23·3	—20·2	—23 2	—29	—31	—28	—35
0	—14·2	—17·7	—10·7	—19	—23·7	—21	—23·5	—29·4	—32	—28·4	—35·5
—0·4	—14·4	—18	—11	—19·1	—23·8	—22	—24	—30	—32·8	—28·8	—36
—1	—14·6	—18·3	—11·2	—19·2	—24	—23	—24·4	—30·5	—33	—28·9	—36·1
—1·7	—15	—18·7	—12	—19 5	—24·4	—23·8	—24 8	—31	—33·2	—29	—36·2
—2	—15·1	—18·9	—13	—20	—25	—24	—24·9	—31·1	—34	—29·3	—36·6
—2·2	—15·2	—19	—14	—20·4	—25·5	—24·2	—25	—31·2	—34·6	—29·6	—37
—3	—15·5	—19·4	—14·8	—20 8	—26	—25	—25·3	—31·6	—35	—29·7	—37·2
—4	—16	—20	—15	—20·9	—26 1	—25·6	—25 6	—32	—35 5	—30	—37·5
—5	—16 4	—20·5	—15·2	—21	—26·2	—26	—25·7	—32 2	—36	—30 2	—37·7
—5·8	—16·8	—21	—16	—21·3	—26·6	—26·5	—26	—32·5	—36·4	—30·4	—38
—6	—16 8	—21·1	—16·6	—21·6	—27	—27	—26 2	—32·7	—37	—30·6	—38·3
—6·2	—17	—21·2	—17	—21·7	—27·2	—27 4	—26·4	—33	—37·7	—31	—38·7
—7	—17·3	—21·6	—17·5	—22	—27·5	—28	—26 6	—33·3	—38	—31·1	—38·9
—7·6	—17·6	—22	—18	—22·2	—27·7	—28·7	—27	—33·7	—38·2	—31·2	—39
—8	—17·7	—22·2	—18 4	—22·4	—28	—29	—27·1	—33·8	—39	—31 5	—39·4
—8·5	—18	—22·5	—19	—22·6	—28·3	—29·2	—27·2	—34	—40	—32	—40
—9	—18·2	—22·7	—19·7	—23	—28·7						

CHAPTER XI.

SOURCES AND MANAGEMENT OF HEAT.

HEAT plays an important part in changing the state and properties of bodies, and we, therefore, devote a chapter to the various modes of applying that agent in chemical operations. The processes dependent upon its action are, principally, FUSION, IGNITION, CALCINATION, INCINERATION, ROASTING, DEFLAGRATION, REDUCTION, CUPELLATION, SUBLIMATION, DISTILLATION, DIGESTION, DECOCTION, BOILING, SOLUTION, EVAPORATION, CRYSTALLIZATION, and DESICCATION.

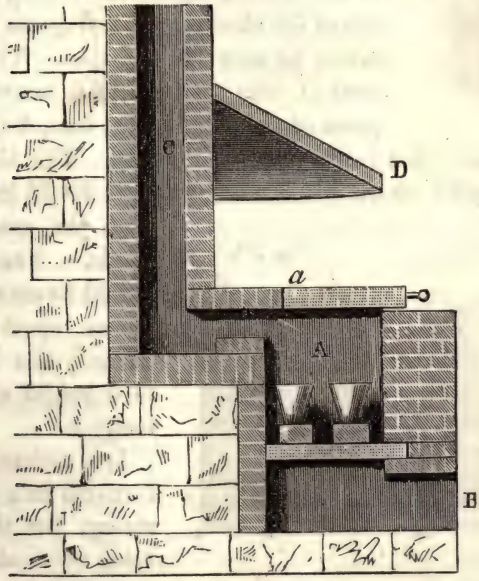
FURNACES.—Laboratory furnaces differ in construction according to the uses for which they are designed. The main parts of every furnace are the body in which the heat is produced, the grate or bars upon which the fuel rests, the ash pan for receiving the residue, and smoke-pipe for conducting off the gaseous products of combustion.

Most laboratories at the present day have a stationary wind or

air furnace set in brickwork. Being applicable only for crucible operations, its usefulness is limited. In private experimental laboratories, the gas sand-bath, explained at p. 66, and one of the portable furnaces about to be mentioned, would be far more efficient and convenient. The object should be to select such an arrangement as will admit of the greatest extent of application, and, therefore, a public institution with the jack, Fig. 14, will only need, besides, a Barron's table, a small charcoal furnace, and the usual gas lamps, to be amply provided for the accomplishment of any furnace experiments. Still, for the sake of giving completeness to our work, we proceed to describe the common form of a,—

Wind Furnace.—This is a close furnace, in which the draught of the chimney urges the fire, instead of a bellows, as in blast furnaces. Fig. 123 shows a vertical section. The body A, may

Fig. 123.



have its interior square or circular, though the latter form is most convenient and economical for fuel, and should abut against a high chimney. The ash-pit B is separated from the body of the furnace by movable, cast-iron, bars, which form a support for

the fire-brick on which the crucibles rest, as well as for the coal used in heating them. The lateral flue, connecting with the chimney C, should be short and contracted at the throat, so as to promote the perfect combustion of the gases before they pass off, and thus economize heat as well as increase the draught. It must also be fitted with a damper. All the interior of the furnace must be lined with tile or brick made of refractory clay; and the ash-pit should have tubes leading from the outside of the apartment, for supplying currents of air to the burning fire, and augmenting the heat. The mouth of the furnace, which is the opening for the introduction of fuel and the crucibles, may be a sliding door of cast-iron, lined internally with a soap-stone slab, as a protection against the fire, as shown at *a*, or it may be hung to the chimney wall by chains working on pulleys, so as to move vertically instead of horizontally. An opening in the centre, fitted with a soap-stone plug, serves for observing the progress of the operation as may be desirable. The cast-iron hood D, over the furnace, is to avert the progress of uprising sparks, dust, &c., and carry them off, through a valve, into the chimney. The dimensions of the pot may be 10–12 inches diameter, and 20–24 inches height from the grate-bars upwards. The grate-bars should be set three-fourth inches apart; and the chimney-flue should run to a height of about 30 feet.

Fig. 124.

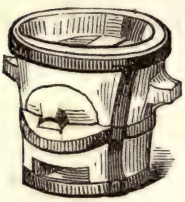


Fig. 125.

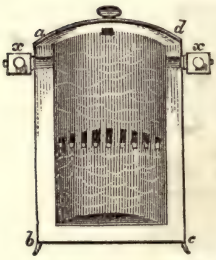
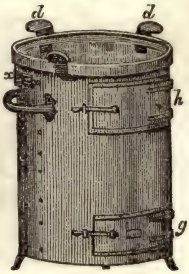


Fig. 126.



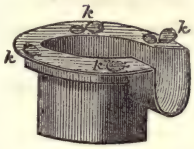
It is useless to multiply furnaces in a small laboratory, for they occupy room which may be wanting for other purposes, and, therefore, a selection should be made of one which in its arrangement is applicable to all the necessities of the chemist. One of either, with a small charcoal furnace, Fig. 124, such as may be bought at any crockery shop, for table use, will comprise all that is required of this sort of apparatus.

Universal Furnace.—Figs. 125, 126, exhibit this furnace, the cylindrical form of which is to be preferred on account of its producing a higher heat with less fuel than any other. It is of strong plate-iron, and lined in the body and dome with refractory fire-clay. Its dimensions are twenty-four inches in height, and nine inches in diameter. The body, *a*, *b*, *c*, *d*, is capped with a ring of the same circumference as the clay cylinder beneath. The doors are shown at *g* and *h*. The circular openings, *x*, *x*, opposite to each other, are for the passage of tubes, and when out of use can be closed by the plugs accompanying the furnace for that purpose. The interior of the furnace, as seen from above, is shown by Fig. 127. The knobs, *e*, *e*, *e*, projecting inwardly, serve as supports for vessels which are smaller than the mouth of

Fig. 127.

Fig. 128.

Fig. 129.



the furnace, whilst the iron juts, *d*, *d*, *d*, directed outwardly, are rests for the larger; this arrangement being necessary, in both instances, to the perfection of the draught. The iron jacket, Fig. 128, adapted to the opening, *a d*, Fig. 125, forms a support for

Fig. 130.

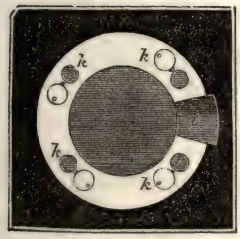


Fig. 131.

the double sand-bath, Fig. 129, for retorts, and other glass vessels. The slope on the side of the sand-bath is for the exit of

the neck of the retort; and the circular openings, *k*, *k*, *k*, *k*, Fig. 130, are fitted with covers, by which to augment or decrease the draught, as may be required.

A supplementary sand-bath, Fig. 131, is made with a broad extent of surface for digestions, evaporations, &c.

The dome, Fig. 132, confers the powers of a wind furnace when high heat is required. As this chimney becomes too hot to be handled, it is removed when heated with suitable tongs, the form of which is shown in Fig. 133.

Kent's universal furnace, which is an improvement upon the above, is shown by Fig. 134. The body is fourteen inches high, by seven inches in diameter, and in material and general construction is similar to the one just described. There are six doors:—one at the base for the admission of air, another in the middle for the entrance of the fuel and for the reception of the muffle used in cupellation. The door in the dome is for the purpose of feeding the fire in crucible operations; and that in the

Fig. 132.

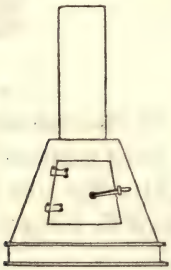


Fig. 134.

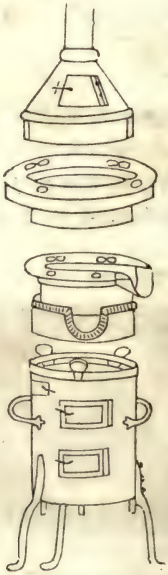


Fig. 133.

side, at the top, for the reception of the neck of a retort, or of a sand-bath. There are two lateral openings, opposite to each

other, for the passage of tubes, or of an iron bar as a support to the rear end of a muffle.

The two circular openings, by which it is coupled with the pipes connecting it with the laboratory flue, are closed by movable plugs. In crucible operations, the smoke-pipe should lead from the top opening, and in evaporations, from the aperture in the back. The openings in the flue must be above the level of the furnace.

An opening at the base is for the introduction of the mouth of a bellows, by which it may be converted into a blast furnace. This implement may be used in the following manner:

1. *As an evaporating and calcining furnace.*—As very high heat is seldom required for evaporations, the body of the furnace alone answers every purpose. For small operations, or when but a small fire is required, its capacity may be diminished by inserting an inner cylinder of baked clay. To increase the draught, all the doors should be closed, and to augment still further the heat, as is necessary in the calcination of certain substances, the dome and chimney may be used. In this latter case, by means of the door in the middle, the progress of the operation may be examined without removing the chimney dome, or cooling the interior of the furnace.

The sand and other baths, which have their places upon the top of this furnace; serve for digestions, evaporations, &c., in vessels which require the abatement and equalization of the heat by intermedia.

2. *As a reverberatory furnace.*—This kind of furnace is adapted to operations demanding a high temperature, as in the heating of crucibles, tubes, &c., and also in sublimation and similar processes requiring the application of a steady heat to all portions of the vessel, rather than a very great heat to any one part of it.

The furnace is rendered reverberatory by the use of the dome, which allows the vessel to be entirely surrounded by flame, and reflects back the heat upon and around its whole surface, and thus by equalizing the temperature, prevents the condensation of vapors in the upper parts,—an important object in distilling from beaked vessels.

Coke or charcoal is the fuel generally used, the latter being pre-

ferable for a furnace of small dimensions; and the draught may be increased by lengthening the chimney.

The crucible, or vessel, must be placed in the centre, supported upon half of a fire-brick, in such a situation that the cold air ascending through the grate may not prevent the heating of its bottom. The fire is then kindled and maintained by fresh supplies of fuel, which are added carefully so that they may not, whilst cold, come in contact with the hot vessel and occasion its fracture.

3. *As a wind furnace.*—Wind furnaces are used for the vitrification of mixtures, reduction and fusion of metals, and for other operations requiring a prolonged elevation of temperature.

The combustion is urged by the draught of a flue, and the degree of heat within the furnace depends upon the size and height of the chimney into which the flue passes. The intensity of the heat is increased by so proportioning the dimensions of the furnace and the chimney that their diameters are equal, and the height of the latter twenty to thirty times the diameter of the former.

The furnace may be converted into a wind furnace by putting on the dome, closing all the openings, and giving a free access of air to the grating through a pipe attached to the circular nozzle in the hearth space, and leading into one of the flues of the laboratory chimney. The smoke-pipe may lead into the same flue, and both should be fitted with dampers for the regulation of the draught.

4. *As a blast furnace.*—Blast furnaces are serviceable for expeditiously producing a great intensity of heat, and are used for fusions and other operations which require more power than that of the wind furnace.

The combustion is urged by a current of air forced through a pair of double bellows, the nozzle of which leads into the circular opening near the base of either of the aforenamed furnaces. The connection should be tightly adjusted with LUTE, so as to prevent any escape of air. The arrangement otherwise is exactly the same as for the wind furnace.

In blowing the blast, let the stream of air entering the furnace be small at first, and be gradually increased as the temperature

becomes higher. The maximum heat can be hastened by weighting down the bellows, and thus augmenting the force of the blast.

Sefstrom's (*Berzelius*, vol. 8), and Aikin's (*Faraday*, p. 95), blast furnaces are said to give heat sufficient to melt felspar.

The blast may be furnished to the preceding furnaces from the pneumatic table, Fig. 45, through a flexible leaden pipe, connected at either end by means of coupling-screws. As the lead pipe might be softened by a too great proximity to the heated furnace, the opening in the ash pit of the latter to which the former is to be attached, should be fitted with about two feet of iron gas pipe, so as to prevent direct contact.

5. *As an assay or cupel furnace.*—The same arrangement which is directed for a reverberatory will convert it into a cupel furnace; the only additional requisite being a muffle, Fig. 135, for the reception of the cupels in assaying operations.

Fig. 135.

A very convenient and more efficient furnace for CUPELLATION is shown by Figs. 136, 137.

It is made of refractory fire clay, and hooped with strong iron bands fastened together by screws, in order that it may better withstand the high temperature to which it is subjected.

A, A′, is the ash-pan, of diameter sufficient for the reception of the body of the furnace B B′. The door *c*, is for the exit of the cinders, and the ingress of the air. The larger opening D′, in the body of the furnace, is for the introduction of the muffle, and a corresponding one D, opposite, for a prism-shaped support of baked clay for maintaining the muffle in a horizontal position. The mouth-piece, supported by a small platform, affords the facility of admitting or preventing the access of air to the interior of the muffle.

There are other openings throughout the circumference of the body immediately above the grate, for increasing the draught when necessary.

In the part of the dome E is a door for the introduction of the fuel. The two openings *e e* are for the introduction of a poker to arrange the fire.

At the top of the furnace is a dome G G, to which is adapted a sheet-iron pipe for increasing the draught.

Fig. 136.

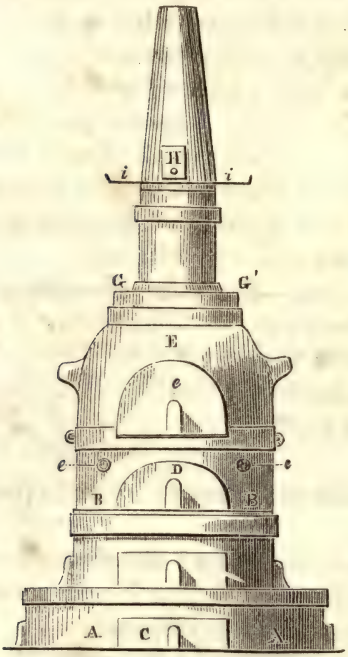
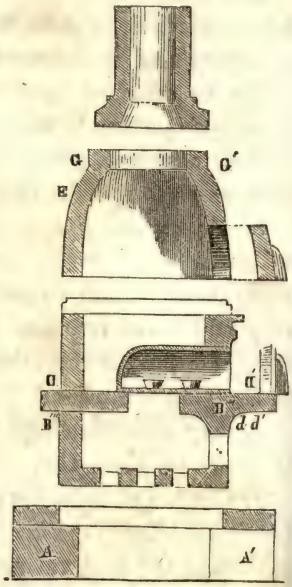


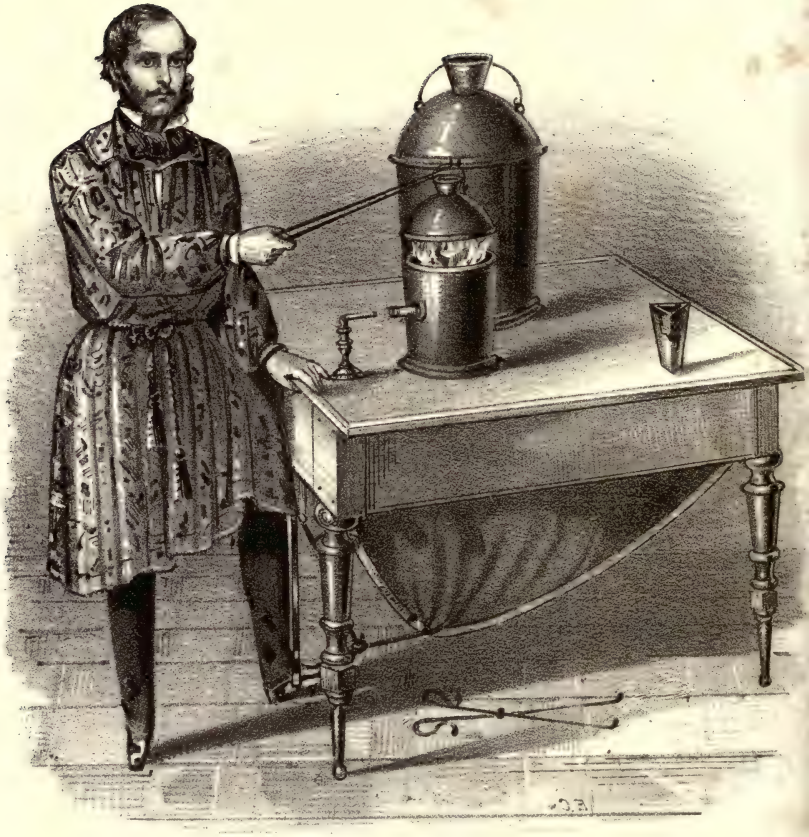
Fig. 137.



A sliding door H, and a small circular gallery *i i*, as a support for heated coals, afford additional means of increasing the draught.

Barron's Furnace.—By far the most convenient and generally useful furnace is that known as Barron's Wind-Chest Table and Blowpipe, a portable apparatus of simple construction. It is not only readily manageable, and economical as to fuel, but works with great efficiency, being applicable for all the purposes of melting, fluxing, forging, annealing, and dry assaying.

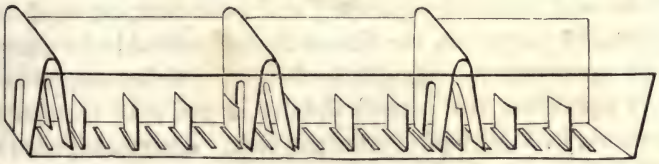
It consists of a table with a cast-iron top, beneath which are a wind-chest and bellows, as shown by Plate 3. Rising from the wind-chest and protruding through the top of the table are movable blow-pipe jets, which convey the blast to the furnaces, of which there are four sizes, the smaller being capable of melting 4 to 8 ounces of gold, and the larger fifty times that weight.



The crucibles to be heated are placed in the furnace in the usual manner, and the furnace itself is placed on the table top, which forms a convenient support, so that its air-tubes at the base will be immediately in front of the nozzle of the blow-pipe. The bellows is worked by a treadle, which is adjusted so as to produce a steady and easily controllable blast. Melting operations require from 5 to 20 minutes, according to the quantity of material under process. The arrangement of the furnace for assaying, annealing, or forging, is after the usual manner. By substituting an oil or grease lamp for the furnace, the apparatus becomes a powerful soldering blow-pipe.

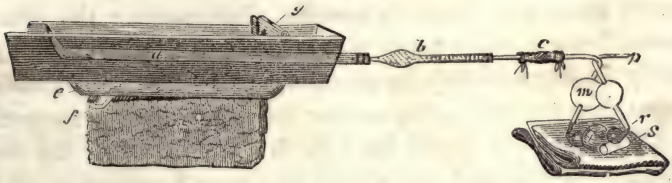
Liebig's Furnace for Organic Analysis.—This is a small sheet-iron furnace, with movable partitions and screen, in which the

Fig. 138.



combustion of organic bodies is effected by a charcoal fire. Fig. 138 shows its interior. Fig. 139 gives a side view of the furnace,

Fig. 139.



containing a combustion-tube under process connected with organic analysis. It is twenty-four inches in length, three inches in height, and three inches in width at the bottom, diverging to four inches at the top. The combustion-tube *a* passes through a circular opening in the closed end of the furnace, and rests upon sheet-iron supports, Fig. 140. The grate consists of a series of slits at the bottom of the furnace, which are distant from each other about half an inch. The sheet-iron screens, Fig. 141, are used to confine the fire to certain parts of the tube.

Fig. 140.

Fig. 141.

The furnace is used upon the table, and should rest upon a stone of length nearly equal to its own.

Management of Furnaces.—All furnace operations should be conducted under a stationary hood, so that the carbonic acid and other noxious exhalations may have an escape from the laboratory, and the sparks and heated air emitted, be prevented from endangering the comfort and safety of the apartment.

If the furnace is without feet, it should rest upon a stone block, and never directly upon the floor or the top of the table, for its heated bottom may occasion a conflagration.

Coal, coke, and charcoal are the fuel most used. Coal is the least available, for it contains sulphur, and yields a large amount of ash and clinker, which choke the grating, and it should never, therefore, be used in the blast furnace.

Coke and charcoal, separately and combined, are used for all the furnace operations, the former being preferable for assays at a high temperature. Weight for weight, their amount of heat is nearly equal, but the greater density of the coke enables it to give more, bulk for bulk, by ten per cent. Charcoal ignites most readily, but coke is more durable. Moreover, when of good quality and free from sulphurous and earthy matter, it gives but little ash or clinker. By mixing the two together, the good qualities of both are obtained; but charcoal alone is preferable for heating glass and porcelain vessels. Before using the coke or charcoal, care must be taken that it has been freed from dust and dirt by sieving, and that the pieces are about the size of a walnut, so that they may pack away neither too loosely nor too compactly.

All of the fuel should be kept in a dry place, for the vapor arising from wet coal and condensing upon the surface of fragile vessels which are being heated, will be apt to cause their fracture.

The crucibles should be placed in the centre of the furnace, upon a support, which may be a piece of fire-brick or a cast-iron trivet, as shown by Fig. 142. This support answers also for stone-ware retorts; but a preferable form for this purpose is the crow's-foot, Fig. 143. The size of these latter implements is regulated by the proportions of the vessels which they support.

Fig. 142.

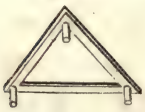
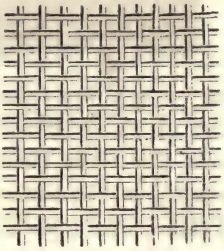


Fig. 143.

For supporting basins and flasks over the evaporating furnace, an iron trellis of strong wire, Fig. 144, is necessary. A series of these iron trellises, of different sized meshes, will be found convenient for adapting the heat to glass vessels, tubes, &c.

Fig. 144.



In placing the vessels in the fire or in the sand-bath, they must be made to stand firmly, and as near to the centre as possible, so that they may be equally heated all around. To prevent damage to them by a too sudden rise of temperature, the fire must be urged gradually, and when the operations are finished, they should be left to cool with the furnace, or, if taken out, be transferred to a cool sand-bath, so that their refrigeration may not be so sudden as to cause fracture.

When the vessel, to be heated over the naked fire, is of less diameter than the mouth of the furnace, this latter may be proportionably lessened by means of a suitably adapted flat iron ring. These rings, Figs. 145, 146, are also useful when it is required to

Fig. 145.

Fig. 146.

concentrate the heat of the furnace in the centre of the vessel, and therefore it is advisable to have a series of them, the centre openings of which should decrease gradually so as to render them convenient for all sized vessels.

Before commencing operations the furnace must be entirely freed from ashes and clinker, and the coal placed around the vessel in layers. When a fresh supply of fuel is requisite, it may be added through the door-

Fig. 147.

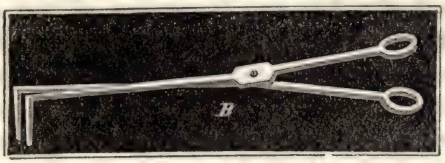


Fig. 148.

way made for the purpose. The auxiliary apparatus of a furnace, other than that already mentioned, are an ordinary iron poker for clearing the grate; and several pairs of tongs. One of these latter, for adding lumps of coal to the fire, should have the form shown by Fig. 147. Those for managing the crucible in the furnace and for removing it whilst hot, may be of either of the patterns presented by Figs. 148, 149.

Fig. 149.

LAMPS.—Lamps are convenient and economical substitutes for furnaces in table operations. Being less cumbersome and more cleanly than the latter, they are readily manageable and always ready for use; and they also afford the means of more rapidly multiplying results.

The amount of heat to be obtained by these instruments depends upon their size and arrangement. A properly constructed lamp may be made subservient to all the requirements of the nicer heating operations of the laboratory, from gentle digestion or evaporation to those processes which require a very high degree of heat.

The heating power of the flame is most active immediately beneath its summit, and the vessel should be *gradually* brought into direct contact with that portion. The vessel should be heated more gradually in proportion to the thickness. When thick glass or porcelain or other fragile bad-conducting material is suddenly heated, the heated part expands while the rest does not, and this unequal tension of two adjacent parts causes the cracking or fracture of the vessel. There is, therefore, a great advantage in employing glass or porcelain vessels of thin structure, for the heat being rapidly conducted through them, the liability of fracture is diminished. As strength is, however, often required and thicker vessels must be used, the above principles

of expansion and conduction must be remembered when they are employed.

In order to apply a small fire to a large surface, the heat may be diffused by setting the vessel in a SAND or WATER BATH, or, which is convenient and more cleanly, a plate of sheet metal or wire gauze may be placed between the vessel and the fire. It is safer not to allow the vessel to touch the plate or gauze. Iron or brass gauze may be used, although fine copper gauze is preferable, because more durable.

The combustible or fuel most commonly used in chemical lamps is alcohol, though pyroxylic spirit and lamp oil are occasionally employed.

Alcohol flame gives no smoke or unpleasant odor, the product of combustion being only carbonic acid and water; while lamp oil, especially where the supply of oil to the wick is insufficient, produces a black carbonaceous deposit upon the bottom of the vessel which occasions a loss of heat by radiation.

The alcohol flame moreover does not have the same injurious effect upon bodies in contact with it as the oil flame with its sooty deposit; nor does it hide from view the contents of test-tubes, retorts, and other vessels, by blackening the glass.

A strong heat may be obtained from alcohol, but in tedious processes, which require a long-continued uniformity of temperature, the *best* lamp oil, or *better*, olive oil, should be used, such, for example, as experiments with the mouth blow-pipe.

Pyroxylic spirit is much less objectionable than lamp oil, and, according to Bolley, nine-fourteenths cheaper than alcohol in heating capacity. The many other advantages of the latter, however, give it the preference over all other combustibles as fuel for chemical lamps. It should be of about the sp. gr. of 0·85. Lamps burning, should always be extinguished before having the supply of fuel renewed, so as to prevent liability of explosion. The spirit is then gradually introduced from the tubed bottle, Fig. 55, p. 83, until the reservoir is nearly full. This mode prevents its running out, and diminishes the risk of overflow from too large a stream. When the lamp is not in use, the wick should always be covered with the extinguisher to prevent loss by evaporation.

Fig. 150.

The tongs accompanying these lamps are a pair of surgeon's forceps, of such a form as shown by Fig. 150. As they are liable to become oxidized by constant exposure, it is better to have their prongs plated with platinum. This precaution lessens the liability of debasing the contents of crucibles with iron oxide which may become detached when they are handled with rusty tongs.

We proceed to speak of such lamps as are suitable to laboratory purposes.

Glass, Spirit, Lamp.—This is a small glass lamp, like the one shown in Fig. 151. The body is the reservoir for the alcohol. To the neck *b* is adjusted a copper circular shield *c*, with a tube in its centre for the passage of the wick, which should be of cotton, and similar to that used for tallow candles. The shield should rest upon, rather than within the neck, otherwise its expansion by the heat may cause the breakage of the glass. A minute opening drilled in the shield is also requisite for the escape of vapor in case the alcohol should become heated. The glass cap *a*, ground interiorly, so as to fit hermetically to the neck of the lamp when not in use, prevents the evaporation of the alcohol, and the consequent impregnation of the wick with water, which renders its relighting difficult.

Fig. 151.

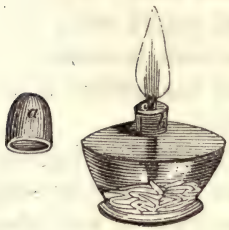


Fig. 152.

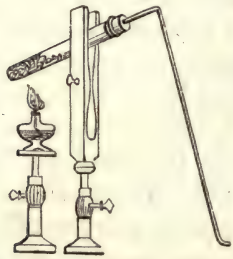


Fig. 153.

The lamp must, however, be invariably extinguished before putting on the cap.

These lamps are useful for heating small apparatus, such as

test-tubes, Figs. 152, 153, and reduction-tubes, and for larger vessels which require only a gentle heat, as shown in Fig. 154. They are generally supplied with spirit through the mouth occu-

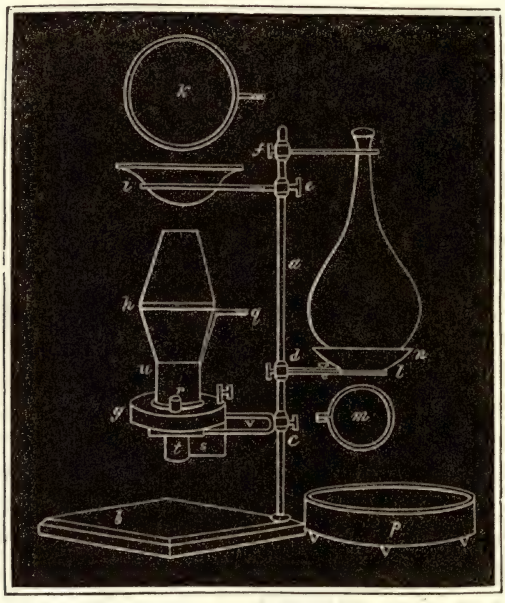
Fig. 154.

pied by the wick-holder. A much safer and more convenient mode would be to pour it through a channel in the shoulder; and lamps are now being made with this provision, as shown in the drawing which illustrates Bunsen's mode of igniting filters. The heating power of the lamp may be greatly augmented by the use of a small conical chimney, made of sheet-mica or copper. It may rest upon the shoulder of the lamp; but to permit access of air must be perforated at the base with large holes, or else raised on feet.

Berzelius's Lamp.—Fig. 40 at page 64 represents this lamp with the improvements recommended by Mitscherlich and Liebig. It should be made of thick sheet copper or brass, and brazed instead of being soldered together. Its form is that of an Argand lamp, with a circular body or reservoir *g*, Fig. 155, which receives its fuel through the stoppered opening *r*. The mechanism contained in the framework *s*, and communicating with the cylinder *t*, allows the elevation or depression of the wick at will. The only communication between this portion of the lamp and the reservoir is by a small tube through which the alcohol is supplied to the wick. The chimney *u* may be movable and adapted to a

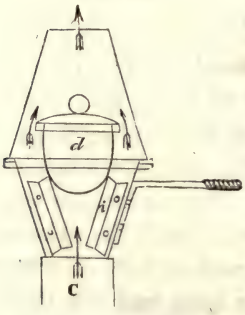
flattened socket soldered to the side of the inner circumference of the reservoir, or else be hinged in the same position, so that it

Fig. 155.



may be thrown back when the lamp is to be lighted or trimmed. Surmounting the chimney is a crucible jacket *h* with a handle *q* adapted to the socket or thumb-screw. The crucible, with its movable cover *d*, Fig. 156, is placed in the centre of the sheet-iron jacket, upon supports, so as to receive the full force of the flame. It is designed to protect the crucible from all air save that which passes up the chimney. The whole arrangement is shown by Fig. 156, c being the chimney of the spirit lamp, and the arrows showing the direction of the flame, which passes unobstructed upward. All atmospheric air save that which passes up the chimney being excluded, the heating power of the lamp is greatly increased.

Fig. 156.



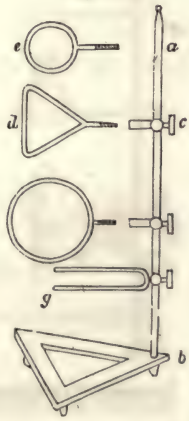
The lamp, as seen by the figures, is mounted upon a fork *v*,

which slides upon the upright of the support *b*. This upright is a smooth wrought-iron or brass rod, screw cut at its lower end, and firmly fastened to the walnut foot *b* by means of a nut. The foot serves as a ballast, and at the same time as a bed for a large capsule, which is a convenient receptacle for any matter which may be accidentally spilled from the heating vessel. The pan *p* is intended for the same purpose when the support is occupied on either side. There are other appliances which add to the convenience of this lamp. They consist of thumb-screws and sockets *d e f* for holding the iron wire rings *m l i k*. These rings, varying in diameter, serve as supports for the vessels employed, and to steady those which are tall, like the flask shown in the figure, a clamp *f* is requisite. The thumb-screw, to which the rings are attached, slide upon the upright rod, and allow the elevation or depression of the heating vessel at will. The iron plate sand-bath *n* is very useful for digestions in beaker glasses, which will not safely bear direct contact with the flame.

The fittings of this and all other chemical lamps should combine lightness with strength, so as to avoid the dissipation of too much heat by excess of metal.

Fig. 157 exhibits a lamp support not very dissimilar to the preceding, but with a cast-iron triangular foot *b*, of weight sufficient to prevent the lamp from being upset by the superposition of heavy vessels. The iron triangle *d* is a very convenient substitute for the ring when a crucible is to be heated, as that shape affords a better support. The rod *a* of brass or iron is from twenty to twenty-four inches in length. The fork *g* for the lamp, and the rings, are all adapted to the thumb-screws which hold them steadily until they are to be replaced by others of different form or size for different and larger vessels.

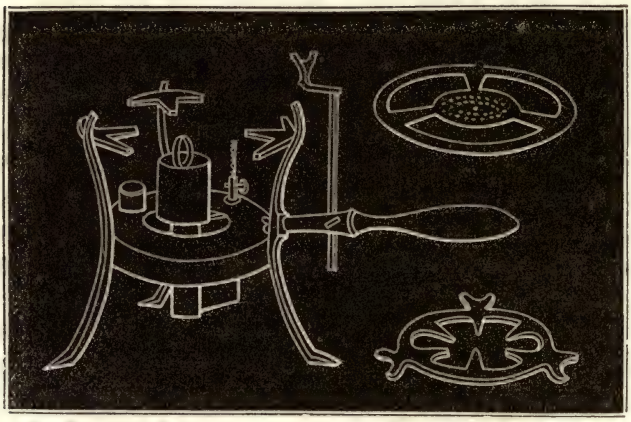
Fig. 157.



A very convenient modification of Berzelius's lamp for boiling in large vessels is shown by Fig. 158. It is supported by three feet of solid brass. Adjusted to its wooden handle is a brass crook for supporting the necks of beaked vessels, retorts, and the like. This crook can be lowered

or elevated at will by means of the thumb-screw by which it is fastened. Two rings accompany it, one, of open work, for the support of capsules, broad and round bottomed vessels; and the

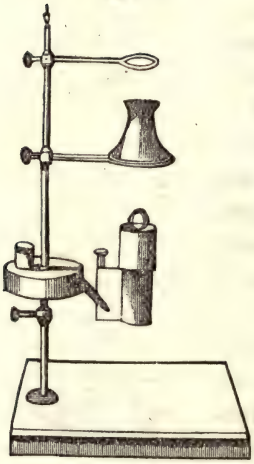
Fig. 158.



other cullendered with fine holes, for the distribution of the heat to flat-bottomed glass vessels.

This is a powerful lamp, and is more convenient for large vessels than the lamp mounted as before described. Luhmè, who first recommended this form, also advises that there be no direct communication between the reservoir and the circular space containing the wick, because such an arrangement is promotive of accidents. When the lamp has burned for a length of time and nearly all the alcohol is consumed, the reservoir becomes filled with vaporized spirit, which may explode when it is relit after being refilled. All this is prevented by forming the connection by means of a tube. The Berzelius lamps of recent manufacture are made with this improvement.

Fig. 159.



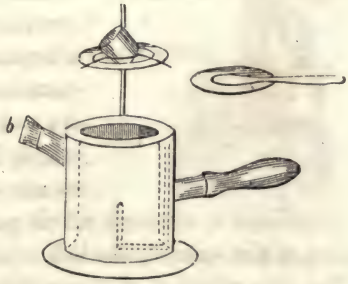
Either of these lamps, and all others in which spirit is consumed, must be provided with a metallic ex-

tinguisher to protect the wick and prevent evaporation of the alcohol.

Rose's Lamp.—This lamp, Fig. 159, also constructed upon the principle of the Argand burner, gives an intense heat. It possesses the advantage recommended by Luhmê of having the reservoir at a distance from the burner, so that the spirit remains unheated during the longest operations. The wick is regulated by a rack and pinion as in the Berzelius lamps, and its mode of management is precisely the same.

The Russian Lamp.—This apparatus, Fig. 160, affords a very powerful heat in a few minutes. It consists of a strong double brass cylinder or box, the interior arrangement of which is shown by the dotted lines in the cut. A piece of tube terminating in a jet passes from the exterior to the interior chamber, rising nearly to the top of the former. The fuel is supplied through the aperture *b*, closed with a cork, and not with a brass cap. The lamp is known to be fully charged when the spirit begins to flow from the jet. The inner chamber is then to be filled with the same spirit to within half an inch of the apex of the jet. The ignited spirit in the inner chamber heats that in the outer, and causes it to boil, the pressure of the vapor forces the boiling spirit through the jet in a powerful stream, which of course becomes immediately inflamed, and acts as an energetic blast, producing heat enough to ignite a platinum crucible, placed above it, to whiteness. The triangle which supports the crucible must be of platinum, and the ring upon which the triangle rests of very stout iron wire in order to resist the fusing effect of the flame.

Fig. 160.



By enclosing the crucible in a jacket (Fig. 156), for which the rim of the lamp will form a sufficient support, the action of the blast is greatly expedited as well as augmented.

There are certain precautions necessary in the use of this lamp, to guard the operator against accidents. Before introducing the alcohol, it is proper to be assured that the jet is

free from impediment by blowing through it. The cork stopper *b* must be put in somewhat loosely, so that it may offer no resistance should a stoppage occur during the operation. For still greater safety, that part of the lamp should be turned from towards the experimenter.

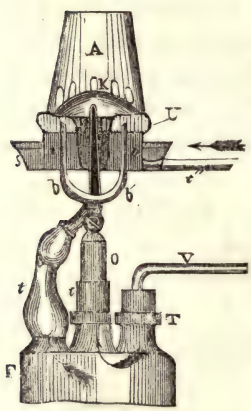
Pyroxylic spirit is the fuel recommended; and it is said that a lamp of this construction, 3½ inches in height, 3¼ inches in diameter, will burn with a charge of four ounces of spirit for thirty minutes, which is long enough for most fluxions with carbonated alkali.

Hart's gas furnace, hereafter described, is intended by the inventor as a substitute for the Russia lamp.

Deville's Blast Lamp.—This implement, the invention of St. Clair Deville, is designed for producing high temperatures with the use of alcohol, wood spirit, kerosene, camphene, and similar fluids, as fuel. Those hydro-carburets which have the lowest boiling-point and give the densest vapors, afford the greatest heat. The lamp is applicable for fusions, fluxing, and ignitions, and a few seconds only are necessary to raise the heat equal to that of melting iron.

Fig. 161 is a drawing of the apparatus. "It consists of a reservoir F, with three tubulures above, T *t t'*. By means of the blast of a blow-pipe table, the air is injected into F through the tube V, which is inserted in T. The tubulure *t* carries the vertical tube O, which has a stop-cock at R, and divides above into the two arms *b b'*, which pass into a metallic box U, and terminate in its upper part with open extremities cut off obliquely. The box U contains the burning fluid *e* partly filling it; and it connects with a reservoir by *t''*, which is kept at a constant level. The centre of this box is a cylindrical tube, closed below, through which passes the blow-pipe *e*, a continuation of the tube *t'*, the left tubulure (in the figure) of the flask F. The tube which is at the middle of the box U, and envelopes the blow-pipe *c*, has several small holes *u u* communicating with the empty (or upper) part of the box U.

Fig. 161.



"Above the blowpipe, and resting in a furrow in the top of the box U, there is a copper cup K, pierced at the centre with a hole for the passage of the jet of vapor which escapes from the holes *u u u*, after the bellows are put in action.

"To prevent the burning fluid from becoming too much heated there is a trough S containing water. Before lighting the lamp, the fluid in L is heated till the water in the trough boils; then the bellows are made to act, and the jet of vapor is lighted; after which the heat disengaged by the lamp is sufficient to continue the vaporization of the fluid.

"Above the box L there is a chimney A having a series of holes around near its bottom for drawing in air on the flame of the apparatus."

Nunn's Blast Lamp.—In this apparatus, steam is made to accomplish the purpose of a blow-pipe table in a very simple and efficient manner. The fuel may be either alcohol, oil, or tallow, but each requires its peculiar burner.

The boiler is constructed after the manner of a still-body, and with a glass tube running up its external side to indicate the level of the water in the interior. Descending from about two inches above the boiler, and down through the top to within an inch of the bottom, is a supply-pipe. The pipe is close to the internal side of the boiler, and terminates at its outer projection with a stop-cock attachment, to which is coupled a piece of vulcanized india-rubber tubing. A safety-valve and steam-pipe complete the arrangement.

The boiler being filled with water to half its capacity is then heated to boiling under a regulated pressure, and loss by evaporation supplied by a slight and continuous stream of fresh water admitted through the supply-pipe. The steam is then let through the pipe, and directed into the centre of the flame of the heating medium.

When alcohol, naphtha, or other volatile liquids are used, the jet is continued sufficiently long to volatilize a portion of the fuel, before the latter is ignited. Then after the vapor is ignited, the steam is again let in, and the current maintained as long as is required. It is necessary that the burner should be constantly above the boiler, else the steadiness of the blast will be embarrassed by accumulation of condensed steam. In an oil flame, the jet of steam is made to issue from the centre of the wick.

Gas may also be used with this apparatus even more advantageously than oil or alcohol; it being only necessary to employ a burner like those adapted to compound blow-pipes, and admitting steam through one nozzle and gas through the other.

The Table Gas Lamp.—Gas is by far the most economical source of heat, being always ready for use, easily manageable, and cleanly. It already replaces coal furnaces in the nicer ignitions, fusions, &c. As the implements connected with its use become perfected in detail, it will supersede all other means of applying heat in a large majority of laboratory operations. It may be conveniently led to any part of the laboratory through flexible caoutchouc tubes, for which purpose one end of these latter is fitted with a brass nozzle for adjustment to a gallows screw at the mouth of the gas tube-feeder pending over the operating table. The other end terminates in either an Argand, single jet, or other suitable burner, according to the purpose for which the flame is to be applied.

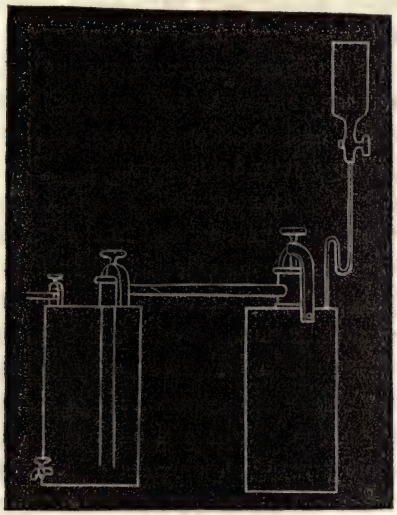
A single jet answers very well for the small gas stands; but for use with the blow-pipe table, an Argand burner is necessary.

The gas lamp, Figs. 41, 42, which has been fully described at pp. 64, 66, supersedes all other heating apparatus for table operations. Crucibles, capsules, and retorts, are alike readily heated by it, and even distillations on a large scale may be successfully performed. To effect the latter object, the upper half of a black lead or clay crucible may be placed around the lamp, provided with an opening on one side for the beak of a retort to pass out. The lower half of the crucible, with its bottom broken off, is then inverted over the whole, and the hole at the top loosely covered to allow the escape of the products of combustion. By this arrangement, the heat of the flame reverberates through the dome, and increases the effect to such a degree that several pounds of mercury may be distilled at once from the red oxide.

Gas being in general use in the large cities and towns, an ample supply can be obtained from the works established for its manufacture and distribution. But, in the country and thinly inhabited districts which are not thus favored, the consumer must depend upon private means for this convenient and economical heating as well as illuminating agent. Upon a limited, but sufficient scale, for the purposes of a small laboratory, it may be made

from grease with a portable and inexpensive apparatus, devised by Kent, and shown in the annexed drawing.

Fig. 162.



The material to be used is the refuse fat of the kitchen, a gallon of which, in its melted state, will yield 100 cubic feet of oil gas, sufficient to feed a bat-wing burner for upwards of seventy hours.

It consists of a wrought iron retort, thirteen inches high and six inches in diameter, with a large opening at the top for the passage of lumps of coke with which it is to be three-fourths filled. The coke is used to increase the extent of the heating surface so as to facilitate and hasten the generation of the gas.

The retort is to be heated to low redness, but no higher, otherwise the gas becomes decarbonized. The oil is supplied to the retort in a thin but constant stream from the funnel, through a small hole in the key of the stop-cock. The retort is connected by an iron tube with a copper reservoir immersed in cold water, for the purpose of cooling the gas and collecting a portion of undecomposed oil which passes over. An additional receiver renders this apparatus applicable to the purposes of illumination or heating. All the pipes and appliances for either are furnished

with the apparatus by the manufacturer, to order. The retort requires to be occasionally cleansed, but at no other time has it to be necessarily opened.

Large vulcanized india-rubber bags make excellent gasometers for small quantities of gas; but for 100 cubic feet, it will be better to have a sheet-iron bell well payed over, internally and exteriorly, with plumbago paint. The cistern for its reception can be sunk in the yard, and for the above quantity its dimensions must be 6½ feet diameter and 4½ feet depth.

Gas is by far the most economical source of heat, being powerful, always ready for use, readily manageable, and cleanly. For all the nicer ignitions, fluxions, and fusions it replaces the furnace, which is less convenient, and requires tenfold the time for its action. In five minutes, by the aid of the table blow-pipe, Fig. 45, and appropriate burners, we can often satisfactorily complete processes which with a furnace would require an hour. This saving of time and fatigue is an important consideration when the operations are to be multiplied or rapidly repeated. By "driving a current of air obliquely and somewhat downward through the Argand burner, the process of cupellation may be accurately performed on three hundred grains of lead."

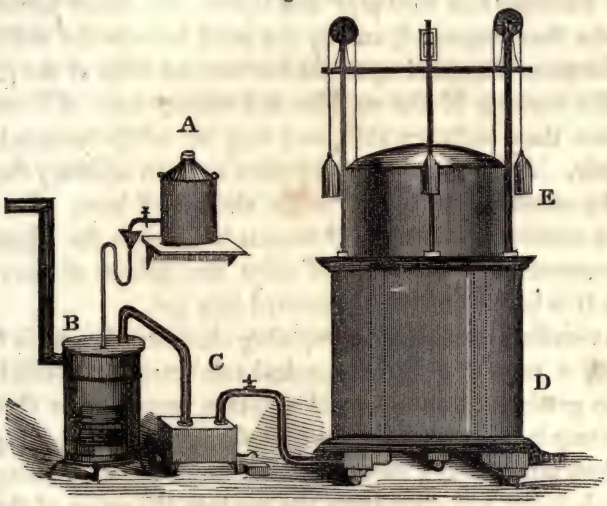
Gas may also be made, readily and economically, from rosin or rosin oil. A very convenient arrangement for the purpose is that exhibited by the following drawing, and known as the "Maryland Co.'s Portable Gas Apparatus." One, costing $350, complete, including expense of transportation and erection within a reasonable distance from the manufactory, will produce and store, in three hours, 300 cubic feet of gas, at a total expense of 50 to 75 cents, only 3 gallons of rosin oil and twelve cents worth of anthracite coal being consumed in the operation. Moreover, very little labor or attention is required; and as each burner needs but two cubic feet of gas per hour, the product of a single distillation will be amply sufficient to feed five burners for four hours, nightly, during a whole week. Machines of larger capacity cost in proportion.

The apparatus, being of simple construction, is very manageable. It consists of

"1st. An oil can or reservoir, 'A,' for the raw material.

"2d. A stove, 'B,' in which is set the retort or Generating Apparatus.

Fig. 163.



"3d. A siphon box or condensing box—'C.'

"4th. The water-tank—'D.'

"5th. The gas-holder, 'E,' which hangs into the water of the tank like an inverted tumbler.

"The reservoir is a simple cylindrical vessel, containing the oil from which the gas is generated. The retort is an iron hollow cylinder, with a spheroidal bottom and flat cover, bolted and screwed to a projecting rim. The stove containing the retort is of sheet or cast iron, arranged upon the most approved plans to economize the heat. The siphon box, or condenser is a cast iron vessel, with a movable lid bolted and screwed upon it. This is divided into compartments and half filled with water, with a siphon attached, so as to keep the water at all times to its proper level. The water-tank, in which the gasometer floats, is made of wood or iron, and placed upon the surface of the ground, or which is better, sunk to the level of the water. The gas-holder is of sheet iron, suspended upon fixed pulleys, and forms the receiver for the gas, when generated and ready for consumption. The reservoir communicates with the retort by a feed-pipe, or by a feed-pipe and cock, through a siphon screwed into the cover of the retort.

"This siphon connects with a tube suspended perpendicularly in the middle of the retort, pierced with small holes in its lower end. Through this feed-pipe and siphon, the liquid passes into the tube thus suspended, and by the small holes at the end of the tube becomes dispersed upon the bottom and sides of the retort.

"The working of the machine and management of it requires no more than ordinary skill, and may be safely intrusted to a domestic. A fire is made in the stove as in an ordinary furnace, and the retort is heated to a bright cherry-red heat. The cock is then opened to allow the oil to pass in through the pipes from the reservoir, upon the heated sides and bottom of the retort, where it is instantaneously converted into gas.

"Ascending from this decomposing chamber, the gas is forced through a superstratum of chemical substances, suspended upon an iron grating, for its purification, into a vacant upper chamber, and thence it is conducted by an iron pipe into the condensing box. This iron pipe passing through the cover of the condensing box descends below and discharges the gas into the water of the condensing box. Thence it rises into the vacant chamber above the water, which, becoming filled, forces the gas again into the water under one of the several compartments above referred to, into a second chamber, and then on through consecutive baths before it finds its exit from the last of the series of consecutive chambers.

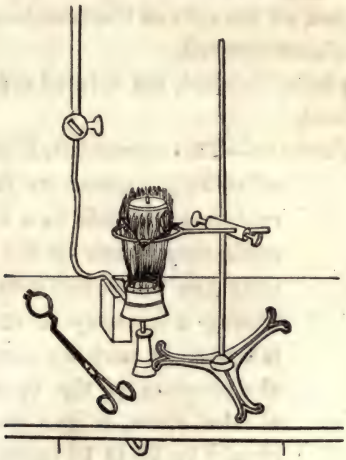
"This exit is through a pipe which communicates from the condenser with the water-tank into which it enters, and passing through the water above, again descends, and discharges the gas into the water for its last bath,—thence it rises into the vacant chamber of the gasometer ready for use. Connected with the siphon of the condenser is a small covered vessel, which receives the impurities washed from the gas in its passage through the baths. The machine as above described, occupies a space of eight feet by twelve, and in height thirteen feet, with the tank upon the ground. If the tank be sunk, then the height will be but seven feet.

"The material used is an oil from rosin, though not what is generally understood as rosin oil. It is an earlier, cheaper, and better product of colophony, decomposable at a lower, and therefore more economical degree of heat."

The supply of this material is inexhaustible, and any anticipated demand can scarcely enhance the price, which is now 12½ cents per gallon. Each gallon of the raw material may be safely estimated to make one hundred cubic feet of gas.

When gas is used it is only necessary to bring the Argand burner, Fig. 46, over the jet 3, Fig. 45, and to depress it so

Fig. 164.



much that its orifice may extend a short way into the flame for heating a vessel of small surface, Fig. 164, and still further for vessels of greater superficies. The gas being turned on and inflamed, the treadle is then worked with the foot, slowly at first, until the current of air thus forced up through the tube changes the white and quiet flame into one of a pale reddish tint and ragged outline. If too much air be driven through, the flame becomes bluish, and the heat becomes less intense.

When a lamp is used, it is necessary that it should have a circular Argand burner, which is to be placed over the jet 3, in such a position that the orifice of the latter projects through the centre of the burner, just beyond the top of the wick. The length of the flame being proportional to the elevation of the wick, the latter must be adjusted accordingly by the screw and rack before being ignited. The flame being of the proper height, the treadle 4,

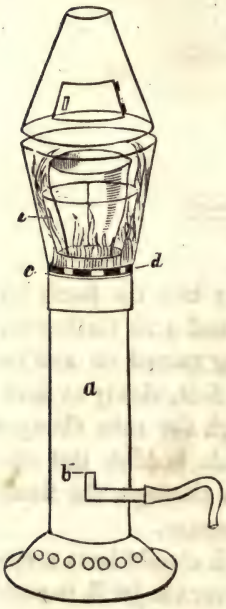
Fig. 45, is to be worked at first slowly, for the heat must be gradually applied, and then more rapidly by increasing the motion of the foot until the blast produces a buzzing sound, when the impulse is continued or moderated as the case may require.

The crucible to be heated is placed upon a wire triangle, resting upon a ring of an upright support, as shown in the figure, and is placed over the FLAME, so that it may be surrounded by the upper or hotter portion (BLOW-PIPE). If the flame is smoky, and deposits carbon on the side of the crucible, the blast must be increased or the flame lowered.

The operation being finished, the covered crucible is left to cool before being opened.

Beale's Gas Furnace.—This apparatus, Fig. 165, gives a heat of sufficient power to fuse a silicate with carbonate of soda in a few minutes. It is made very much in the form of an ordinary gas stove, but with a movable door, having a gateway to afford a view of the interior, as may be necessary to observe the progress of the operation. The body of the stove, a gas and air-chamber *a*, should be 10 to 12 inches high and 3 to 4 inches in diameter. The tube *b* conveys the gas to the chamber, where, becoming mixed with air, it then passes upward through the meshes of the wire gauze diaphragm *c*, where it is ignited and allowed to burn. The circumference of the rim, just above the diaphragm, is pierced with holes for the free admission of air to the burning flame. The support for the crucibles consists of iron pieces projecting from a broad iron ring *e*, made to fit the furnace. These latter parts being movable, they may be replaced by others adapted to the various sizes of crucibles.

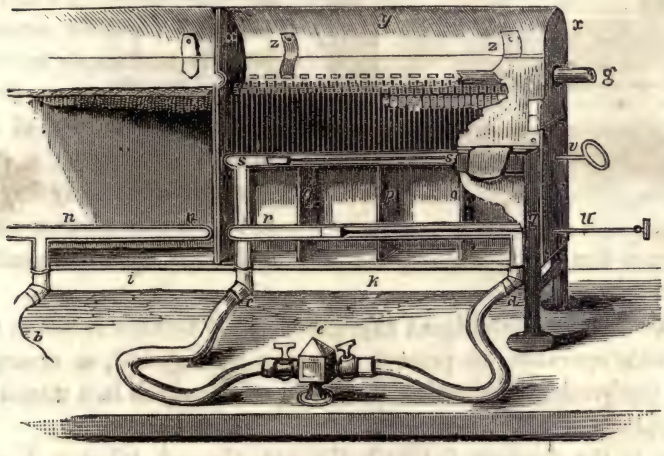
Fig. 165.



Hoffman's Gas Furnace.—This arrangement, shown by the accompanying drawings, Figs. 166 and 167, is designed as a substitute for Liebig's Charcoal Furnace, in Organic Analysis, and

for heating long tubes in a horizontal position. Its advantages over coal fire are so obvious that we will not enumerate them; for though faulty in some respects, it is still a very efficient

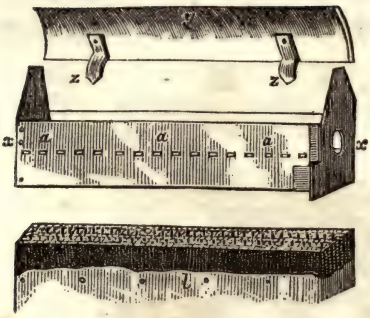
Fig. 166.



implement, which gives a strong heat, and with the means of accurately regulating it, according to the requirements of the process. As in other gas furnaces, the gas is burned after having become mixed with sufficient air to produce, in its combustion, the maximum of heating power. We are indebted to Liebig's Hand-Book of Organic Analysis for our drawings and description.

The furnace A, made of wrought-iron plate, consists of three separate compartments *h*, *i*, *k*, which are supported by a stout iron stand *l m*. Of these three compartments, the two first *h* and *i* are simply rectangular boxes of iron, open at the bottom and covered at the top with wire gauze, and supplied by horizontal perforated gas pipes *n*, *n*, Fig. 167. The last compartment *k* differs from the preceding in being subdivided into four smaller chambers by three diaphragms *o*, *p*, *q*, the gas being supplied by two pipes instead of one. The lower pipe *r r* is a counterpart of the gas-pipe *n*, *n*, of the other compartments. On the other hand, the upper pipe *s*, *s*, supplies the gas to two rows of fine vertical tubes, similar to those in Leslie's burner, the extremities of which project through the wire gauze cover of the compartment, as seen in Fig. 167. Each pipe is provided with

Fig. 167.



air-tight pistons, by which the heat is entirely under the control of the operator. A frame *x*, above the wire gauze, as shown by Fig. 167, supports the tube containing the matters to be heated; and in the same drawing, there is a view of one of the side pieces *y*, fastened to the frame by tongues *z*, in such a manner as to form a dome for reflecting the heat downwards upon the combustion-tube.

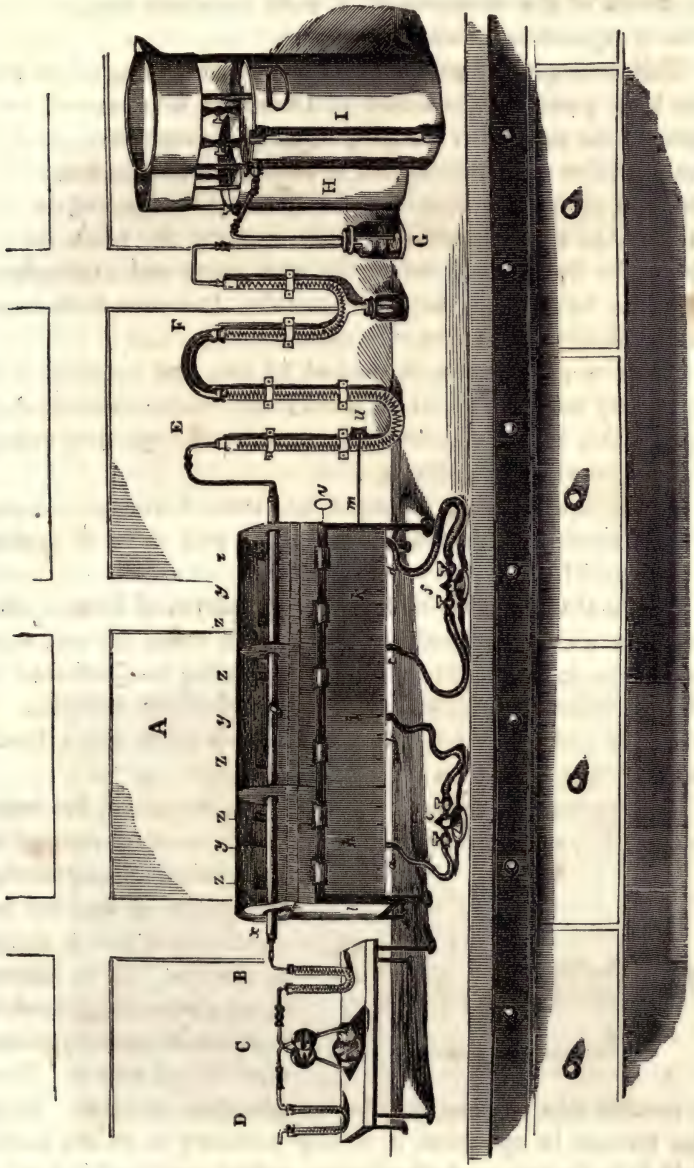
To afford an intelligent expression of the manner in which this furnace operates, we present a view of it, Fig. 168, as arranged for performing combustion in an organic analysis in a mixed atmosphere of air and oxygen.

A is the furnace, fed with the gas, through tubes *a*, *b*, *c*, *d*, which are fitted with stop-cocks *e*, *f*. The combustion-tube, containing the matters to be heated, and supported in the usual manner, as shown at *g*, communicates, in the usual manner, with a chloride of calcium tube B, a bulb apparatus C, and a U tube D, for solid potassa. In the rear is a series of tubes containing hygroscopic substances, for abstracting carbonic acid and moisture from the air and oxygen, as they pass from the gasometers H, I, into the combustion-tube. Of this series, E contains solid potassa, and F pumice-stone impregnated with sulphuric acid. There is a third piece or bottle G, containing oil of vitriol, and which serves the double purpose of a bubble-gauge for measuring the rapidity of the current.

The joints being all tight, gas is then let on through the flexible tube *d* to the lower gas-pipe *r r*, and the piston *u* pushed so far from the inlet as to supply the gas to the chamber *o*, *l* (Fig. 166) only, whilst it is excluded from the other chambers. The air-flame thus obtained keeps the rear end of the combustion-tube at a dull red heat. The cock *c* is next opened, so as to admit a small quantity of gas into the upper gas-pipe *s s*, and the piston at the same time drawn so far from the inlet as to confine the gas

to a very few of the little tubes, at the extremity of which more

Fig. 168.



points of flame are thus produced. Succeeding portions of the

tube are heated at the proper periods by gradually pushing in the piston *u* of the lower tube, and supplying gas to all the chambers of the compartment *k*, until the whole length of the tube is exposed to a uniform air-flame.

This arrangement affords great facility in heating tubes, with the least possible expenditure of labor and time, as well as of money; for the cost of the gas consumed is very trifling, and the heating-tubes are rarely injured or broken, provided sufficient care has been observed to heat it gradually in the first part of the operation. As a great security against cracking the tubes, the gas should be first lighted below the wire gauze and extinguished after the furnace has acquired warmth. It is then to be immediately lighted again above the gauze.

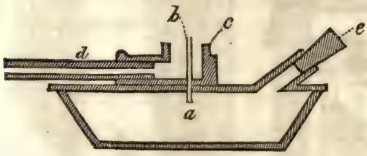
The wire gauze becomes choked by use, and requires to be frequently renewed; on which account the furnace is constructed so that this repair may be easily made by the operator, without the assistance of a gas-fitter.

The apparatus being arranged into three divisions is adapted for operations with short tubes as well as with those of medium and greater length.

Hart's Gas Furnace.—This is a modification of Nunn's Blast Lamp, in which the combined action of a steam jet and a gas flame is made an effective means of producing heat sufficient for all the ordinary operations performed in platinum crucibles. It is simple and inexpensive, and works very much like a Russia lamp, so that it requires very little watching.

The apparatus is formed of a round copper basin *a*, five inches in diameter, and fitted by brazing with a close circular top of the same metal. Rising through the centre of this top is a small copper tube *b*, serving as the jet. It is inserted in an elbow-joint *c*, to which is attached, laterally, a short piece of gas tube *d*. There is another tube opening at *e*, for the admission of water. To set the furnace in operation, it is only necessary to fill the basin *a* half full of water, and after having corked the tube *b* tightly, to place it on the ring of a retort-stand over a gas flame. In the

Fig. 169.

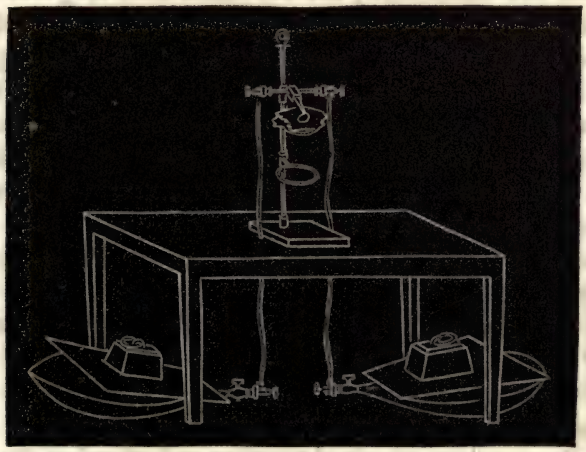


mean time, a flexible tube attachment is made at *d*, for the purpose of supplying gas from one of the laboratory burners. As soon as the water boils and steam begins to issue through the jet, the gas is turned on and lit at *c*. The flame produced is a hot blue brush; and care must be observed to rightly proportion the size of the flame and pressure of the steam current, so as to obtain its maximum of heat, and prevent the former from being extinguished by the power of the blast. The jet must be always kept free, and to this end should be probed with a pin immediately before use.

Compound Blow-Pipe.—This apparatus, known as Hare's oxyhydrogen blow-pipe, is used for the fusion of such refractory but fusible substances as resist the highest power of the furnace. Its action is based upon the intense heat produced by the ignition of combined oxygen and hydrogen gases, and is fully explained under the head of BLOW-PIPE in Booth's Encyclopædia of Chemistry. Explanatory drawings of one of these implements, adapted for large operations in the arts, are to be seen in Appleton's Dictionary of Mechanics and Engineering, vol. i, p. 107. Our remarks will refer to economical forms of the apparatus, suitable for laboratory purposes.

Fig. 170 exhibits Kent's pattern. It consists of two vulcanized

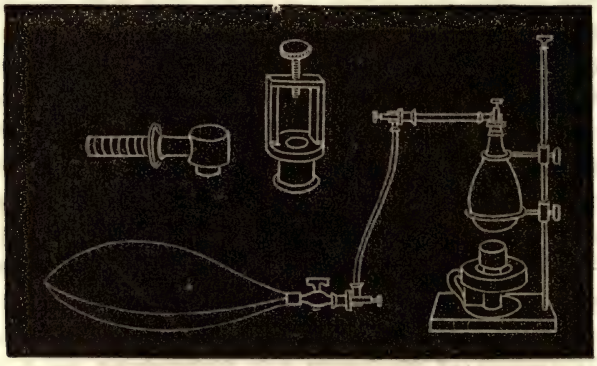
Fig. 170.



india-rubber bags or reservoirs, of twenty gallons or greater capacity. These bags are very flexible, strong, and portable;

one of the above size, when empty, occupying but a very limited space. They are filled, the one with oxygen, and the other with hydrogen gas, each being fitted with a connecting screw and stop-cock, by which they can be adjusted directly to the generating apparatus, as shown by Fig. 171, or with a gasometer, when

Fig. 171.



they are to be charged. The communication between the bags and the jet-pipe above the table is by means of the flexible india-rubber or lead tubes, coupled by gallows screws, Fig. 171. The jets are so divided within the pipe that the gases enter at opposite ends, and consequently are not mixed until they meet at the arm of the jet, which is so arranged that it can be raised or lowered on an ordinary retort stand. By this arrangement, which is a convenient modification of the old double-jet, a jet of oxygen passes through the centre of a circular flame of hydrogen, the mixture and consequent explosion of gases being avoided.

The gradual efflux of the gas from the reservoirs is effected by superposed weights,—a much more convenient mode than that of hydrostatic pressure, which is requisite when metallic reservoirs are used.

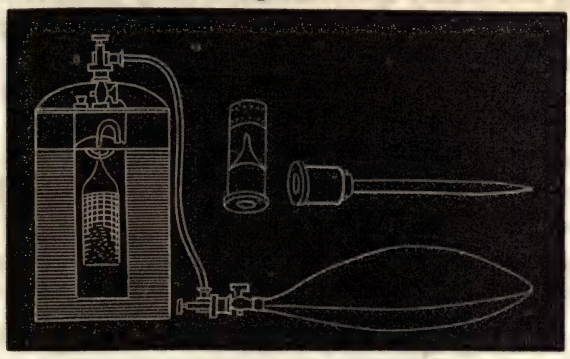
The two gases are very readily prepared. The whole apparatus for oxygen is shown in Fig. 171. The retort, a thin copper flask, is connected with a brass cap and neck by a gallows screw.

Four ounces of good chlorate of potassa, and one ounce of peroxide of manganese are mixed together and placed in the retort, the cap screwed down, and the joints luted with pipe-clay. The heat of a Berzelius lamp, applied as shown in the figure, drives over ten gallons of pure oxygen in fifteen minutes.

The lamp may be removed as soon as the gas begins to be generated and pass over freely, as sufficient heat will be retained for the completion of the operation. The *caput mortuum* of chloride of potassium and oxide of manganese remaining in the retort can readily be removed by water.

Hydrogen can still more readily be obtained from a self-regulating reservoir. Fig. 172 exhibits the apparatus as made by

Fig. 172.



Kent. The copper cylinder which he uses is replaced in other similar instruments by glass. It consists of a japanned copper cylinder, 9 inches high, and 6 inches diameter, with a cover and bell attached.

Within the bell hangs a basket of copper wire, which is to be filled with about ¾ lb. of zinc, in lumps. The outer cylinder is to contain 6 lbs. of cold diluted sulphuric acid, made with 1 part acid to 4 of water.

In the upper part of the bell is a division, forming a receptacle for a strong solution of potash, 2 f. ℥ of which are put into it through the opening in the top, which is then to be tightly stopped.

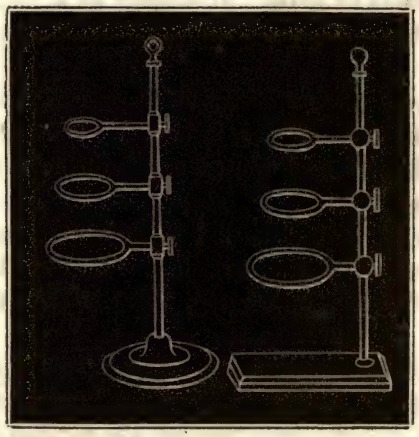
The apparatus being adjusted, and the stop-cocks opened, the dilute acid rises in contact with the zinc, and generates hydrogen gas, which, being forced through the potassa solutions, becomes washed previous to its exit from the stop-cock into the bag. An hour suffices to generate twenty gallons of gas; and, when it is desired to arrest the operation, close the stop-cock so as to produce an accumulation of gas in the bell, and thus dis-

place the acid. The action may be renewed at any time by opening the cock.

Accompanying this apparatus, as shown by separate figures in the cut, are two convenient addenda for other purposes; one a jet, with platina sponge and fixtures, for producing an instantaneous light, and the other for bending glass tubes, &c. They are both readily attached to the stop-cock by their screws. In the first case, the gas is projected against the platina sponge, and becoming immediately ignited affords a ready means of lighting a taper. The sponge, when not in use, should be kept covered and dry.

The oxyhydrogen blow-pipe is put into operation by first charging the bags with gases, placing on their weights, letting on the hydrogen, igniting it, and passing a jet of oxygen through the flame directed upon the substance under process. This substance should rest upon charcoal or fire-brick, and in a cavity drilled for the purpose, so as to prevent its being blown away by the force of the blast. For the same reason, when the substance is in powder, it is necessary to moisten it with water, and compress it in the cavity. The charcoal rest is very conveniently supported

Fig. 173. Fig. 174.



upon one of the sliding rings (Fig. 173), which allows the facility of bringing it near to the orifice of the pipe where the combustion takes place.

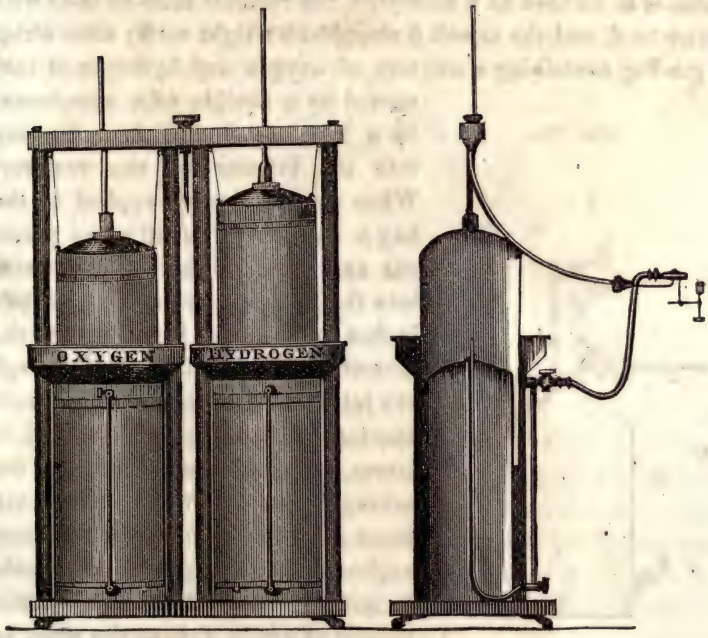
The heat thus produced is very intense, and melts platinum

readily. Coal or illuminating gas may be substituted for the hydrogen.

When this apparatus is used for the purposes of illumination, as in the production of the *Drummond light*, which is produced by the action of its flame upon a cylinder of lime, the nozzle of the blow-pipe must be pointed upwards, so that the flame may have full play upon the incandescent earth.

Another form of compound blow-pipe, as made by Ritchie, is shown in the annexed figure.

Fig. 175.



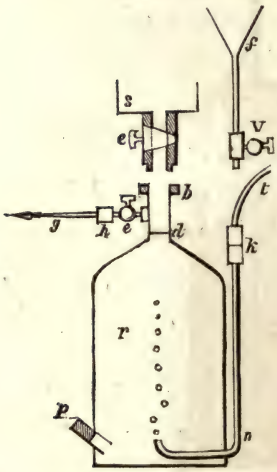
The gas-holders are a pair of metallic vessels placed upon a framework which moves on castors. These vessels consist severally of an outer bell and inner cylinder, the latter being suspended in the former by counterpoise weights concealed in the posts of the stand. Self-adjustment is thus secured in proportion as gas enters or passes out of the gasometer, and very little water need be used.

The drawings show the two gasometers attached as a compound blow-pipe, with all its necessary appurtenances, tubes, stop-cocks,

flexible hose with jets and adjustable holder. As each, however, has its distinct inlet-pipe, screw-plug, &c., they may be used separately for other purposes.

Tate has proposed a form much simpler and more economical than either of the preceding. It moreover answers the double purpose of an oxyhydrogen blow-pipe and gas-holder. It consists of a receiver *r*, Fig. 176, with a shelf *s*, adjustable to *b* by a screw connection. Like other gasometers it is provided with stop-cocks *e*, *e*. The inlet-pipe is at *p*, and the jet at *g*. At the thick part *h* of this jet there is a wire gauze diaphragm. When the apparatus is to be used as a blow-pipe, the receiver must be filled with water to *d*, and the mouth *b* closed with a tight cork; after which a gas-bag containing a mixture of oxygen and hydrogen is connected by a flexible tube attachment to a bent metal pipe *k*, *n*, passing into the interior of the receiver. When pressure is then applied to the bag a current of mixed gases passes out and upwards through the water into the tubular portion *d*, *b*, of two inches height, and ¾ inches internal diameter. Thence it passes through the jet upon the opening of the cock thereof, and may be ignited as it issues. There is perfect safety in the arrangement, for, if by chance, the flame in the jet should rush back, any explosion that it might produce would be trifling and restricted to the small volume of gas in *d*, *b*, as the water in *r* prevents communication with the gases in the bag reservoir.

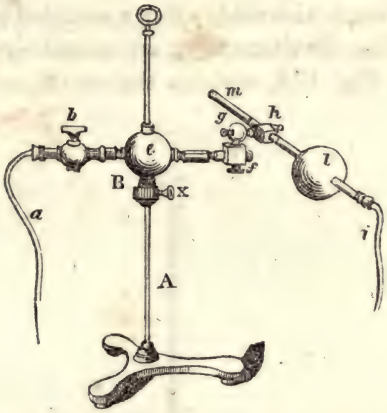
Fig. 176.



To convert the apparatus into a gas-holder, it is only necessary to remove the jet or shut off communication with it by closing the cock *e*, screwing on the shelf at *b*, and replacing the flexible tube and gas-bag by the funnel *f*, *v*. The inlet *p* is then opened for the admission of gas from a flask or generator. Pressure is applied by a column of water descending through *f*, *v*; and the outlet for the gas is at *s*, *e*.

Sonnenschein's Blast-Lamp.—Ritchie has introduced another form of compound blow-pipe, which occupies no more room than a Berzelius lamp, and is both convenient and efficient for blowing glass and heating crucibles to a high temperature. It differs in construction from the preceding, but assimilates to them in principle, the heating medium being the flame produced by combustion of a mixture of atmospheric air and illuminating gas. The whole arrangement is shown by Fig. 177, and consists of an upright

Fig. 177.



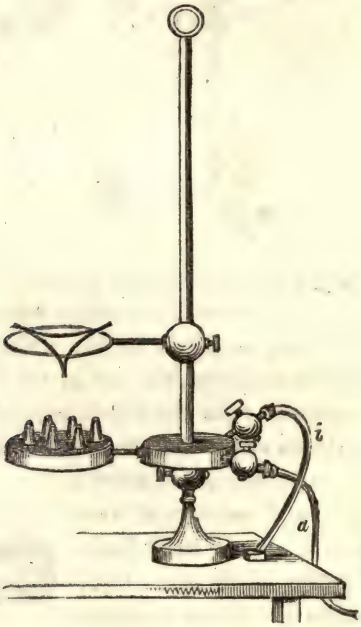
stand A, steadied by a heavy foot, and upon which slides the brass lamp B by its bulb *e*, fitted with a binding-screw X, for adjusting it upon the rod at any required height. Projecting from this bulb are two opposite branches, the one at the left having a stop-cock *b*, with a screw-end *c* for the adjustment of a flexible tube *a*, connected by a gallows screw with the table or building gas-pipe. The right branch is rather more complicated in structure, and consists of two parts, one of which, *e f*, is fixed horizontally in the ball *e*, while the other, *h m*, is appended to it by two movable joints, so as to impart both a horizontal and vertical motion, and thus afford the convenience of giving the jet any desired bearing. The tube *h m*, is concentric, as shown nearly in full size by Fig. 178, so that the gas passes forward uninterruptedly through *e*, *g*, *h*, and between the tubes to the point of issue *m*, where it is met

Fig. 178.

by a current of air emerging from the smaller centre tube, which is distinct from the outer, and communicates with the ball *l*, and thence by a flexible tube *i* with a bellows or blast-table. The inner tube is a quarter inch shorter than the outer one, and ends in a pointed jet, so that the admixture of gas and air takes place just behind the point at which they are ignited. This precaution prevents accident from explosions. To give the apparatus its maximum force the air may be heated as it passes forward by merely placing a spirit lamp under the ball *l*. A veritable *hot blast* is thus produced.

The above lamp is also made after a modified pattern, so as to bring into service, simultaneously, an assemblage of jets. The drawing below, Fig. 179, explains the arrangement, which rests

Fig. 179.



upon the top of a blow-pipe or blast-table, from which rises an air-pipe *i*. The gas connection is made by means of the flexible pipe *a*, and each jet being concentric, the gases only mix at the points of issue, as in the apparatus before described. This combination of jets produces a heat of great intensity.

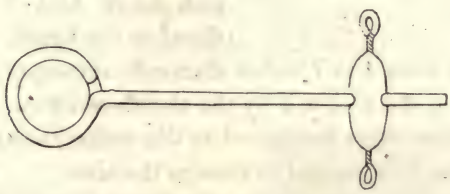
When crucibles are under process with this apparatus, they should be firmly secured upon the supports, and placed either above or below the jet. For ordinary purposes the breath will answer the place of a bellows.

Supports.—In lamp, table furnace, and blow-pipe operations, vessels are maintained in a required position by supports, differing in material and construction with the uses for which they are destined.

A very simple and economical support is shown in Figs. 173 and 174, the only difference between the two being in the shape of the foot, one being rectangular and the other round. It consists of an upright iron rod, from 20 to 24 inches long, and about ⅓ of an inch or more in diameter, screwed into a cast-iron foot, and fastened beneath by a nut. The three projecting rings, of iron wire, 2, 3, and 4 inches in diameter, are held by thumb-screws, which permit their elevation or depression at will.

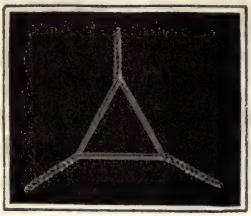
For the larger stands the thumb-screw is of iron, and of the form exhibited in Fig. 164 and Figs. 180, 182, *b*. It is made with

Fig. 180.



two holes, at right angles to each other, and two screws, one for the reception of the iron upright, and the other for the handle of the ring, which can readily be detached and replaced by another of different size. This form of screw and socket prevents the necessity and expense of having the rings attached to the screws. One of these screws will answer for a series of rings, and the latter being of iron wire, the operator can readily form them himself of any required shape. With this arrangement, and a series of different-sized rings, the support is convenient for all its purposes without the expense of a socket for each ring. When the rings are too large for the vessels to be heated, their diameters may be

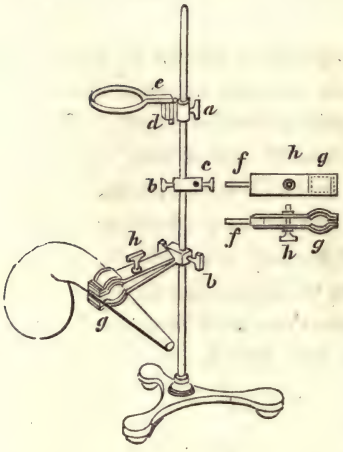
Fig. 181.



diminished by means of stiff wire triangles, Fig. 181, called trivets. They are particularly useful for the support of small crucibles, as is shown in Fig. 41, p. 64. There should be a number of them of different sizes.

Fig. 182 exhibits what is called the "*universal support.*" The foot is of cast iron, and the toes twelve inches apart. The upright rod is of iron, 36 inches long, and $\frac{7}{8}$ in diameter. It is substantially made, for the support of heavy capsules, retorts, &c. The thumb-screw and sockets *b* are of solid brass or iron. A brass vice, 6 inches long, and $1\frac{1}{2}$ inches wide, lined in its mouth with buckskin, is shown at *g*. It is fitted by the arm *f* to the hole *c*, and serves for the support of heavy retorts and other beaked vessels, as shown in the figure. Three solid brass rings, of from 4 to 7 inches diameter, accompany this stand, and are held in the socket *d* by the thumb-screw *a*. As the arm of each of these rings is adapted to the socket, one may replace the other when it is desired to change the size.

Fig. 182.



Wooden supports adapted for tube arrangements, made of boxwood or hickory, and lined with cork or buckskin at the parts intended for grasping, are also convenient and necessary pieces

Fig. 183.

Fig. 184.

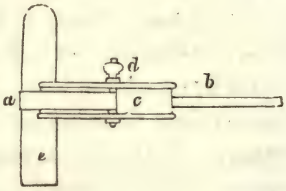


Fig. 185.

of apparatus. They consist of foot, rod, and nut, similar to the iron supports. Their other parts are a wooden vice (Gay-Lussac's), Fig. 183, for supporting the necks of retorts and other

beaked vessels; Gahn's cylinder-holder, Fig. 184, for experiments with gases; and a wooden ring, Fig. 183, as a rest for inverted

Fig. 186.

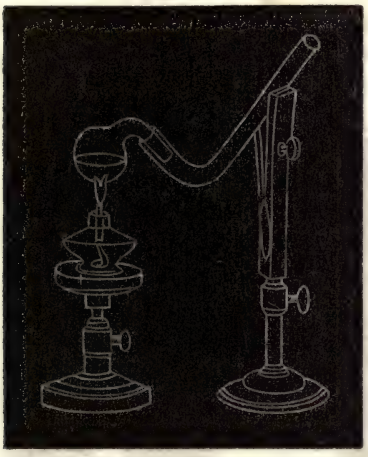


Fig. 187.

flasks. Figs. 186, 187 exhibit an upright retort clamp with a movable joint and wooden screw, by which it can be raised or lowered at pleasure. The stand or lower portion is similar in

Fig. 188.

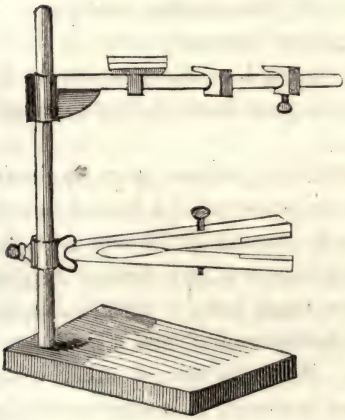
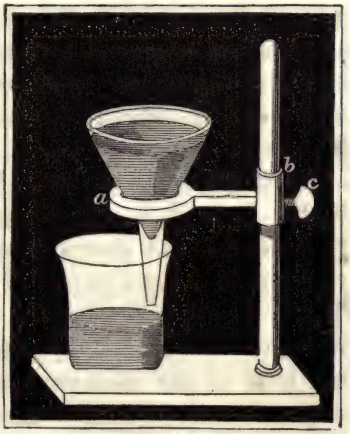


Fig. 189.



construction to D E, Fig. 191. Another form of vertical holder for supporting horizontal tubes, &c., is shown by Fig. 186.

Fig. 188 represents another support, with two sliding arms, the upper one of which is a funnel-stand, and the lower a tube or retort-holder. The funnel supports of the upper arm are adjusted thereto by means of wooden thumb-screws, and may be removed at pleasure. These are less convenient than the single filter-stands, Figs. 189 and 190, though they have the advantage of

Fig. 190.

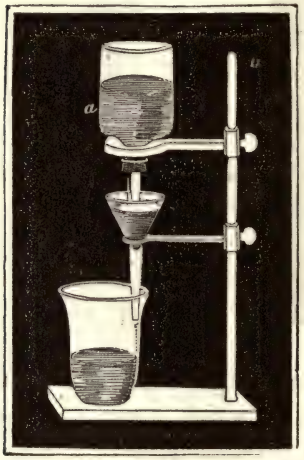
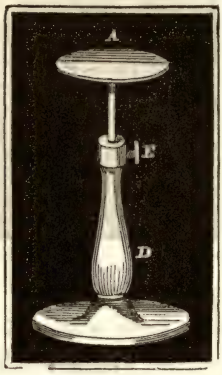


Fig. 191.



allowing several simultaneous filtrations upon one arm, and thus a single stand may do the service of three or four, according to the length of the arm. The uprights of these supports should be screw-cut at the lower end, and fastened to their pedestals by means of nuts, which retain them in place more firmly than any other mode.

A form of stand, known as Berzelius's table support, is shown by Fig. 191. It is of hard wood, and consists of a loaded foot D, supporting a flat disk A, which, by means of its leg and the thumb-screw E, can be raised or lowered to any desired height. This is a very convenient rest for a small lamp or furnace, or for recipients in distillations, when it is required to raise either above the level of the operating-table. When in this or other cases the surface of the supported vessel is round, it is safer to steady it upon a braided straw ring, Fig. 192, interposed between its bottom and the disk.

For supporting tubes and other vessels horizontally, the disk may be replaced by the brass crook, as shown in Fig. 193; and for globular vessels and flasks by the wooden tripod, Fig. 194, or, still better, a wooden bowl. Each of these pieces is adapted to the stand D, and one may replace the other when necessary, the screw allowing them to be raised and steadily maintained at the required height. The height of this instrument, when drawn out to its full length, is twenty inches.

Fig. 192.

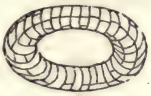


Fig. 193.

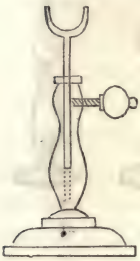
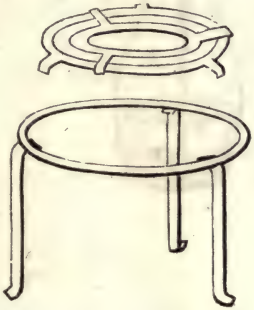


Fig. 194.

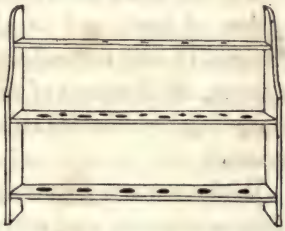
Fig. 195.



As a support for large evaporating vessels over furnaces, an iron tripod, Fig. 195, is very convenient.

The test-tube stand or rack, which is the only support that remains to be mentioned, has been alluded to before, p. 63, Fig. 39. A smaller one for table use is shown in Fig. 196. It consists of two narrow uprights, say ten inches high, of thin poplar wood, which are braced together by three shelves. These shelves are perforated throughout their length with auger-holes for the reception of the test-tubes. The smaller and shorter tubes occupy the upper range; the interval between which and the middle shelf should be less by an inch than that between it and the lower.

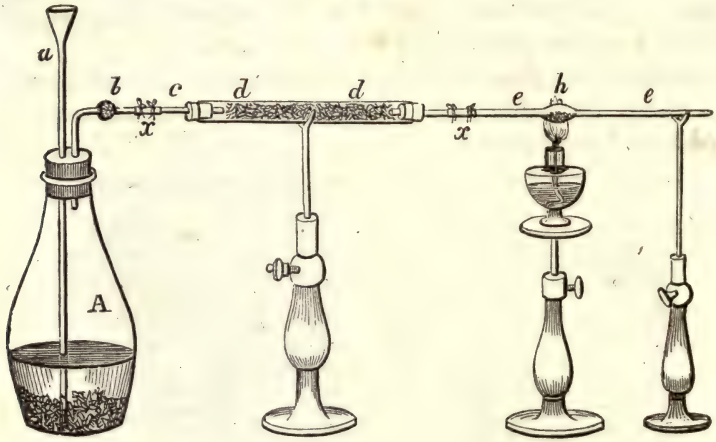
Fig. 196.



The manifold uses of the aforementioned instruments will be more fully explained when we refer to manipulations for which they are applicable. At present, a familiar idea may be obtained by reference to Figs. 152, 154, 155, and to the cut

below, in which several of them, as applied in operations, are included.

Fig. 197.



CHAPTER XII.

BATHS.

Our remarks in this chapter will refer to the means by which the fire heat is moderated and diffused, before being applied to the containing vessels of substances under process. These means consist of baths, which are called vapor, water, saline, metallic, oil, or sand, according to the nature of the interposed bodies employed.

The object of an intermedium is to prevent a too rapid application of heat, and to give greater uniformity of temperature. Inequality and too sudden application of heat being thus provided against, the fracture of vessels and ejection of their contents, and many inconveniencies attending other modes of applying heat, are avoided.

Baths are very convenient for heating substances which require a constant and somewhat permanent elevation of tempera-

ture, and which might undergo decomposition over the naked fire. The temperature to be obtained, is, however, only limited, but by a proper management of the fire any degree of heat, up to the maximum amount which the intermedium is capable of receiving from the means employed, can be obtained.

Baths consist of two vessels of different diameters, and they may be either of metal, stoneware, or porcelain. The outer jacket receives the intermediary body, and the inner one the substance to be heated. As generally constructed, baths are made with but one jacket, the aperture or mouth being of diameter corresponding with that of the heating vessel which is to be placed over it. This arrangement obviates the necessity of an inner jacket, and also of the transfer of the substance which is being heated.

Baths are useful in operating upon organic and other bodies easily alterable by heat. They are also convenient for determining the melting-point of those substances which are fusible at or below the degree of heat which can be imparted to the liquid or vapor of the bath: that temperature being made known by immersing a thermometer at the commencement of the fusion and noting the degree.

In the fluid baths the thermometer may be permanently fixed by means of a perforated cork, closing a circular aperture in the lid. Fig. 120, with the scale upon the stem, exhibits the most suitable form of the instrument for this purpose. The difference in temperature between the bath and the heating substance, which is sometimes very considerable, especially when porcelain or glass is used, may be diminished by keeping the bath always covered. If the vessels have smooth surfaces, the heat obtained previous to ebullition is much higher than in the opposite case. While the bath is in use, care must be taken that the amount of the liquid in the outer vessel remains as nearly as possible the same throughout the process, and the loss from evaporation or exit of vapor should be replaced by frequent but gradual additions of the same fluid.

Steam-bath.—This apparatus forming a fixture of the laboratory has been fully described at p. 46, D and B, Fig. 18, and is very serviceable in extracting vegetable matters, and for rapid

evaporations at temperatures below the heat of direct fire. It is also a convenient arrangement for heating those substances which would be alike injured by direct contact with steam. It affords a temperature of fully 212° F. when used without pressure as at D. When, however, the steam is employed under pressure, as is provided for in B, a temperature of 240° F. can be obtained with ten pounds to the inch. With five pounds pressure the temperature will be 226° F.

For very small operations, the apparatus of Dr. Ure, Fig. 198, is an excellent contrivance. "It consists of a tin box, about 18 inches long by 12 broad and 6 deep. The bottom is hollowed a little by the hammer towards its centre, in which a round hole is cut, of five or six inches in diameter. Into this a tin tube, three or four inches long, is soldered. This tube is made to fit tightly into the mouth of a common tea-kettle, which has a movable handle. The top of the box has a number of circular holes cut in it, of different diameters, into which evaporating capsules of platinum, glass, or porcelain are placed. When the kettle, filled with water and with its nozzle corked, is set on a stove, the vapor playing on the bottom of the capsules heats them to any required temperature, and being itself continually condensed, it runs back into the kettle to be raised again in ceaseless cohobation. With a shade above to screen the vapor-chest from soot, the kettle may be placed over a common fire. The orifices not in use are closed with tin lids. In drying precipitates, the tube of a glass funnel may be corked and placed with its filter directly into the opening of a proper size. For drying red cabbage, violet petals, &c., a tin tray is provided, which fits close to the top of the box within the rim which goes about it. The round orifices are left open when this tray is applied."

Fig. 198.

Water-bath.—The water-bath is used for heating substances at temperatures within that of boiling water. It is very available where bodies easily decomposable by high temperatures are to be

heated, and is also useful for the gradual exhaustion of vegetable and other substances which only give up their soluble matter after long contact with the warm solvent liquid. They also serve to complete evaporations to dryness, which, though commenced on the sand-bath, require at the end a more intense heat. Though seldom employed for the purpose of reducing the temperature very low, it may, by proper management, be made to yield any intermediate temperature from 32° to 212° F.

Every water and liquid bath, whatever its form and the purpose to which it is to be applied, should be so constructed that the vaporized portions can, if necessary, be confined within the vessel and prevented from escaping by other outlets than the safety valve. As proximity of the escaping vapor might be injurious to the substance under process, the escape-pipe should have its exit six or eight inches distant from the sides of the vessel.

Any two vessels of different diameters, one within the other, may form a water-bath, provided the intervening space at the bottom and sides is sufficient to contain the requisite amount of water. Straw at the bottom and sides is an excellent means of steadying the inner vessel and preventing direct contact of its surface with the more highly heated bottom of the outer vessel, a result which would cause the temperature of the inner vessel to be raised above that of the surrounding water.

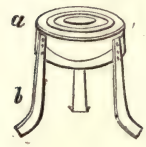
Fig. 199.

A regularly constructed water-bath of convenient form is shown in Fig. 199. "A is a vessel containing the water, *a* the inner

flange for the support of the evaporating dish B, or different circular rings when smaller dishes are employed. *d* is a tube furnished with a stop-cock for the escape of the steam, which, in some cases, requires to be carried still farther off by an additional tube attached to it. The whole apparatus may be heated either by a gas stove or on a charcoal furnace. The water-bath is filled about half full with water. It will be seen that water-baths with cover act more on the principle of steam-baths as soon as the quantity of water which they contain is small. Care must be taken always to replenish the evaporating water by adding fresh, otherwise not only the experiment may be ruined, but the bath itself become seriously injured."

Large tin cups make excellent water-baths for flasks and tall vessels. The bottom of the flasks may rest upon small straw rings which prevent contact with the heated tin, and serve also to steady them. The holes in the lid for the protrusion of the necks of the flasks also assist in this latter respect.

Fig. 200.



A very convenient little bath for small operations, is shown in Fig. 200. It consists of a copper capsule *a*, with a ledge around its interior circumference as a rest or support for the vessel to be heated. In order that it may be applicable to capsules of various sizes, its top is fitted with a series of thick flat copper rings, which afford the power of decreasing the diameter of the outer capsule to suit that of the vessel to be heated.

The whole diameter of the outer vessel is about 7 inches, and when all the rings are placed upon the top the opening in the centre is about 1 inch, but by withdrawing one at a time the size of the mouth can be increased gradually from 1 to 6½ inches, and adapted to any vessel of intermediate size. It would be well to have a small tube projecting from the side, so as to answer at the same time the purpose of a handle, and of an exit pipe for the waste vapor.

This apparatus, as is seen in the figure, is mounted upon a tripod *b*, a convenient support when the small spirit-lamp is used to heat the water. When a stronger heat is required, it can be detached and mounted upon a larger support, and placed over

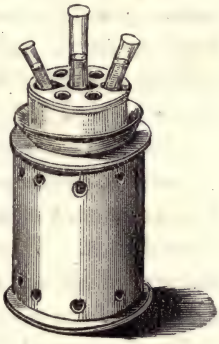
the gas or Berzelius lamp. Fig. 201 represents the apparatus without the tripod and with handles.

Fig. 201.

A porcelain or tin plate placed upon the top of this bath renders it very convenient for drying small filters, precipitates, &c. By increasing the circumference of the bath so that it may have a broad top, and by piercing the latter with circular holes of various diameters, we obtain a means of heating several capsules of different sizes at the same time.

For holding test tubes in upright position, either in sand or water-bath, a support of the form shown by Fig. 202 will be found both convenient and serviceable.

Fig. 202.



The still, Figs. 18, 25, without its head, makes an excellent water-bath for large operations.

Saline baths.—The substitution of saline solutions for water affords a means of obtaining temperatures higher than the boiling-point of that liquid. This kind of bath is very useful for digestions and many other operations. The saturation of the water with salts raises its point of ebullition, but in practice it is necessary to use weaker solutions, otherwise the evaporation of the water would be continually causing the deposition of the salt and the solidification of the liquid to the great inconvenience of the experimenter.

The following table exhibits the boiling-points of the saturated solution of the salts most generally employed for this purpose.

BOILING-POINTS OF SATURATED SOLUTIONS.

Alum,	220°	Sulphate of copper,	216°
Muriate of ammonia,	237	Acetate of lead,	212
Oxalate of ammonia,	218	Chloride of calcium,	355
Tartrate of ammonia,	230	Sulphate of magnesia,	222
Chloride of barium,	220	Cream of tartar,	214
Nitrate of baryta,	214	Chloride of sodium,	227
Acetate of copper,	214	Tartrate of potassa,	224

Sulphate of soda,	213°	Acetate of soda,	256°
Nitrate lime,	303	Nitrate of soda,	249
Carbonate of potassa,	275	Biborate of soda,	222
Chloride of zinc,	320	Carbonate of soda,	220
Rochelle salt,	246	Phosphate of soda,	222
Sulphate of nickel,	235	Nitrate of strontia,	224
Chlorate of potassa,	219	Sulphate of zinc,	220
Nitrate of potassa,	238	Boracic acid,	218
Quadroxalate of potassa,	220		

Chloride of zinc is available at temperatures below 320° F., at which degree it gives off fumes of chlorhydric acid and becomes unsuitable as a medium for the communication of heat. A layer of oil retards the evaporation of the water and promotes the elevation of the temperature of the solution.

The selection of the salt for the bath must be with regard to economy and the nature of the material of the vessels. Corrosive solutions should only be used in those vessels upon which they are without action. The construction of the bath is similar to that shown in Fig. 199.

Metallic Baths.—These baths are only convenient for small operations, because of the difficulty of supporting the weight of a large amount of metal, and of keeping the heating vessels immersed in it. They furnish temperatures higher than either of the preceding, and for greater safety must be heated in cast-iron vessels of form suitable to the experiment.

Mercury would be a convenient menstruum, if it was lighter and emitted, when highly heated, less noxious fumes. On these accounts it is but rarely used, and only in test tubes for heating still smaller tubes. The fusible alloy, composed of eight parts of bismuth, five of lead, and three of tin, forms an excellent metallic bath. It melts below 212° F., and affords very high temperatures, for though it oxidizes upon the surface as its temperature is increased, it will bear a white heat without emitting vapors. Tin melting at 441° F. and lead at 609° F., are both available for a temperature above their fusing-points.

Oil Baths.—Oils in ebullition throw off a very disagreeable vapor, but are otherwise convenient for furnishing temperatures corresponding with and below their boiling-point. Care should be taken not to apply heat sufficient for their decomposition. Even at low temperatures they have the advantage over water,

of losing less by evaporation and of affording facility in regulating the temperature. The oil should, before its transfer to the bath, be heated in an iron capsule for several hours, to expel moisture. The bath consists of a porcelain lined or metallic jacket, of construction exactly similar to that of the water-bath. It affords a temperature of 570° F. A THERMOMETER is necessary for noting the temperature of the bath, to which end its bulb must be kept immersed in the oil.

Sand-bath.—This bath is of more general application for laboratory purposes than either of the others. Its different forms and their appropriate uses have already been fully described at pp. 30, 33, 40, 66, Figs. 9, 11, 17, 43. Sand is used because it is a better resistant of sudden changes of temperature, and affords a uniform heat, greater or less, as may be required, than that of the water-baths. Magnesia and ashes are sometimes substituted, but they are too apt to be driven about by slight currents of air; the former is only used as a bed for platinum or porcelain crucibles, which are to be enclosed in Hessian crucibles and ignited.

A sand-bath may be readily constructed by filling an iron pot with sand and placing it upon the charcoal furnace, Fig. 124, or upon the top of the stove which heats the apartment, or over a gas burner. It is then ready to receive glass or porcelain vessels in which the processes of evaporation, digestion, or distillation may be carried on. Care must be observed, in heating the sand, not to let it exceed the required degree, for otherwise time will be lost in waiting for its fall, as it cools very slowly.

CHAPTER XIII.

THE MODE OF PRODUCING LOW TEMPERATURES.

THERE are many chemical processes requiring the application of low temperatures; and, therefore, it is a duty of this work to teach the means of producing cold artificially. It is accomplished by means of freezing mixtures, which are formed of substances

having a tendency to liquefy in water or other fluid. The absorption of heat, by the freezing mixture, from the body under process, produces a depression of temperature in the latter, varying as to degree with the nature and proportions of the mixed ingredients. This depression of temperature is incident to the disaggregation of the salt or other matter, and its transition from the solid to the liquid state. The heat thus transferred is regarded as a species of latent heat of fusion of the salt, differing measurably from the latent heat of igneous fusion, and has been termed by Regnault "*the latent heat of solution of a salt.*"

Ice and salt, for example, when mixed together, produce a cold of 6°, owing to the rapid melting of the ice and the subsequent solution of the salt in the cold water: the depression of temperature, in this instance, being due both to the latent heat of solution of the salt and the latent heat of fusion of the ice.

Freezing or cooling mixtures are necessary for determining the congealing point of fluid substances; and for this purpose they must surround the vessels containing the latter. When the two have remained sufficiently long in contact to produce the desired result, the temperature of the fluid, at the moment of transition, must be noted by a thermometer, which should be placed in it at the commencement of the experiment. Another thermometer must be simultaneously placed in the freezing mixture, to give assurance that the internal and external temperature are uniform, otherwise the fluid may congeal on the walls of the containing vessel before the interior of the mass has fallen to the proper temperature.

The ingredients composing them should be previously pulverized, and then mixed together without unnecessary delay.

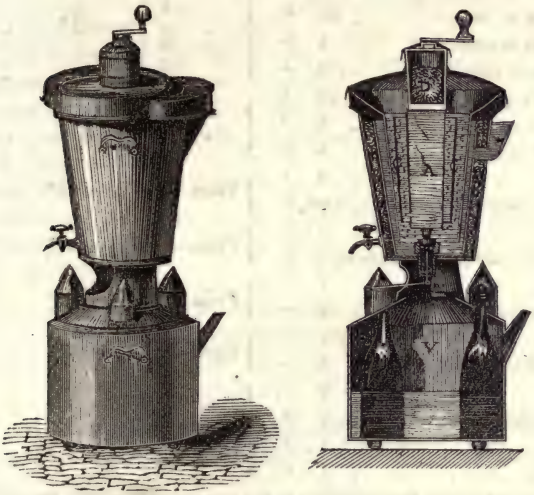
In very small operations, the vessels to be cooled are refrigerated by keeping the surfaces moistened with ether, which, volatilizing rapidly, abstracts and carries off a large amount of heat.

Freezing mixtures afford the facility of making ice at all seasons; and a convenient apparatus for this purpose, as well as for cooling bottles and similar vessels, is the so-called "*Family Ice-box,*" represented by the annexed drawings.

It is composed of a hollow cylinder C, for receiving the refrigerating vessel I, containing the water to be frozen. Another cylindrical vessel A, with a close bottom, sets in the freezing

mixture, and being fitted with suitable projections, and turned by the winch-handle, agitates the mixture, and maintains a thorough contact of the refrigerating body with the inner and outer vessels. If the hollow vessel be filled with water, the latter freezes like the surrounding water. The space I, and also the cover D of the

Fig. 203.



inner cylinder A, are enveloped with raw cotton, which, as a bad conductor, intercepts the heat of the circumambient air. The freezing mixture should be added in three separate portions, to insure its maximum efficiency, and the resulting liquid from each drawn off into the lower vessel V through a lever-cock, before the application of the succeeding portion. The cold water flowing into the receiver V renders the latter a convenient cooling vessel for liquids contained in bottles. Thirty to forty minutes suffice for making a cylinder of ice.

The following tables by Walker and Karsten present formulæ for a variety of freezing mixtures, with the degree of cold which they produce, severally, annexed.

TABLE I.—Consisting of Frigorific Mixtures, composed of Ice, with Chemical Salts and Acids.

Mixtures.		Thermometer sinks.	Degree of cold produced.
Snow or pounded ice,	2 parts	From any temperature to —5°	*
Muriate of soda,	1 "		
Snow or pounded ice,	5 "	From any temperature to —12°	*
Muriate of soda,	2 "		
Muriate of ammonia,	1 "		
Snow or pounded ice,	24 "	From any temperature to —18°	*
Muriate of soda,	10 "		
Muriate of ammonia,	5 "		
Nitrate of potash,	5 "		
Snow or pounded ice,	12 "	From any temperature to —25°	*
Muriate of soda,	5 "		
Nitrate of ammonia,	5 "		
Snow,	3 "	From +32° to —23°	55°
Diluted sulphuric acid,*	2 "		
Snow,	8 "	From +32° to —27°	59
Muriatic acid (concentrated),	5 "		
Snow,	7 "	From +32° to —30°	62
Concentrated nitrous acid,	4 "		
Snow,	4 "	From +32° to —40°	72
Muriate of lime,	5 "		
Snow,	2 "	From +32° to —50°	82
Crystallized muriate of lime,	3 "		
Snow,	3 "	From +32° to —51°	83
Potash,	4 "		

N.B.—The reason for the omissions in the last column of this table is, the thermometer sinking in these mixtures to the degree mentioned in the preceding column, and never lower, whatever may be the temperature of the materials at mixing.

TABLE II.—Consisting of Frigorific Mixtures, having the power of generating or creating Cold, without the aid of Ice, sufficient for all useful and philosophical purposes, in any part of the world at any season.

Mixtures.		Thermometer sinks.	Degree of cold produced.
Muriate of ammonia,	5 parts.	From +50° to +10°	40°
Nitrate of potash,	5 "		
Water,	16 "		
Muriate of ammonia,	5 "	From +50° to +4°	46
Nitrate of potash,	5 "		
Sulphate of soda,	8 "		
Water,	16 "		
Nitrate of ammonia,	1 "	From +50° to +4°	46
Water,	1 "		
Nitrate of ammonia,	1 "	From +50° to —7°	57
Carbonate of soda,	1 "		
Water,	1 "		

* Strong acid 2 parts; water or snow 1 part, by weight.

Mixtures.		Thermometer sinks.	Degree of cold produced.
Sulphate of soda,	3 parts.	From +50° to —3°	53°
Diluted nitrous acid,*	2 "		
Sulphate of soda,	6 "	From +50° to —10°	60
Muriate of ammonia,	4 "		
Nitrate of potash,	2 "		
Diluted nitrous acid,	4 "		
Sulphate of soda,	6 "	From +50° to —14°	64
Nitrate of ammonia,	5 "		
Diluted nitrous acid,	4 "		
Phosphate of soda,	9 "	From +50° to —12°	62
Diluted nitrous acid,	4 "		
Phosphate of soda,	9 "	From +50° to —21°	71
Nitrate of ammonia,	6 "		
Diluted nitrous acid,	4 "		
Sulphate of soda,	8 "	From +50° to 0°	50
Muriatic acid,	5 "		
Sulphate of soda,	5 "	From +50° to +3°	47
Diluted sulphuric acid,†	4 "		

N. B.—If the materials are mixed at a warmer temperature than that expressed in the table, the effect will be proportionately greater; thus, if the most powerful of these mixtures be made when the air is +85°, it will sink the thermometer to +2°.

TABLE III.—Consisting of Frigorific Mixtures selected from the foregoing tables and combined so as to increase or extend Cold to the extremest degrees.

Mixtures.		Thermometer sinks.	Degree of cold produced.
Phosphate of soda,	5 parts.	From 0° to —34°	34°
Nitrate of ammonia,	3 "		
Diluted nitrous acid,	4 "		
Phosphate of soda,	3 "	From —34° to —50°	16
Nitrate of ammonia,	2 "		
Diluted mixed acids,	4 "		
Snow,	3 "	From 0° to —46°	46
Diluted nitrous acid,	2 "		
Snow,	8 "	From —10° to —56°	46
Diluted sulphuric acid,	3 "		
Diluted nitrous acid,	3 "		
Snow,	1 "	From —20° to —60°	40
Diluted sulphuric acid,	1 "		
Snow,	3 "	From +20° to —48°	68
Muriate of lime,	4 "		
Snow,	3 "	From +10° to —54°	64
Muriate of lime,	4 "		
Snow,	2 "	From —15° to —68°	53
Muriate of lime,	3 "		

* Fuming nitrous acid, 2 parts; water 1 part, by weight.

† Equal weights of strong acid and water.

Mixtures.		Thermometer sinks.	Degree of cold produced.
Snow,	1 part.	From 0° to —66°,	66°
Crystallized muriate of lime,	2 "		
Snow,	1 "	From —40° to —73°,	33
Crystallized muriate of lime,	3 "		
Snow,	8 "	From —68° to —91°,	23
Diluted sulphuric acid,	10 "		

Remarks.—The above artificial processes for the production of cold are more effective when the ingredients are first cooled by immersion in other freezing mixtures. In this way Mr. Walker succeeded in producing a cold equal to 100° below the zero of Fahrenheit, or 132° below the freezing-point of water.

The materials in the first column are to be cooled, previously to mixing, to the temperature required, by mixtures taken from either of the preceding tables.

The following table by Karsten, shows the diminution of temperature in degrees Fah., where 1 pt. of salt is dissolved in 4 pts. water.

Salts.	Degrees of cold.
Nitrate of lead,	3·4°
" baryta,	3·8°
Common salt,	3·8°
Sulphate of copper,	4·0°
" potassa,	5·2°
" zinc,	5·6°
" magnesia,	8·1°
Muriate of baryta,	8·1°
Sulphate of soda,	14·6°
Nitrate of soda,	17·0°
" potassa,	19·1°
Chloride of potassium,	21·3°
Nitrate of ammonia,	25·4°
Muriate of ammonia,	27·3°

The following table, also by Karsten, shows the degrees of cold produced by dissolving 1 pt. of a salt in 4 pts. of a saturated solution of another salt:—

Salts.	Sat. solution of.	Degrees of cold.
Sal ammoniac,	Common salt,	15·1°
"	Saltpetre,	22·7°
Saltpetre,	Sal ammoniac,	17·5°
"	Common salt,	16·9°
"	Nitrate of soda,	12·7°
"	" baryta,	17·5°
"	" lead,	17·1°
Glauber's salt,	Common salt,	8·5°
Common salt,	Blue vitriol,	7·4°
Nitrate of soda,	Sal ammoniac,	16·4°
" "	Saltpetre,	16·6°

Salts.	Sat. solution of.	Degrees of cold.
Nitrate of soda,	Common salt,	14·0°
" "	Muriate of baryta,	14·9°
" "	Nitrate of lead,	14·4°
Nitrate of baryta,	Saltpetre,	1·35°
Sulphate of zinc,	Sulphate of potassa,	3·1°

The following table, by Karsten, of 1 pt. salt in 4 pts. of a saturated solution shows an increase of temperature:—

Salts.	Sat. solution of.	Degrees of heat.
Common salt,	Sal ammoniac,	8·2°
" "	Glauber's salt,	3·1°
" "	Saltpetre,	1·35°
" "	Nitrate of soda,	6·8°
Muriate of baryta,	" "	1·15°

By mingling solid lead amalgam with solid bismuth amalgam, whereby they become liquid, Orioli obtained 39·6° of cold. Döbereiner mixed 204 pts. lead amalgam (103 lead + 101 mercury) with 172 pts. bismuth amalgam (71 bismuth + 101 mercury), and obtained a diminution of from 68° to 30·2°; and by adding to the same 202 pts. more of mercury, the temperature fell to 17·6.° By dissolving the powders of 59 pts. tin, 103·5 pts. lead, and 182 pts. bismuth, in 808 pts. mercury, the thermometer falls from 63·5° to 14°.

CHAPTER XIV.

FUSION.

THE liquefaction of bodies by heat, a preliminary step to many processes, is termed fusion. *Igneous* fusion applies to the melting of anhydrous substances, and *aqueous* fusion to the liquefaction of a salt in its water of crystallization.

The modes of performing the process, and the material and form of the apparatus employed, vary with the nature of the substance to be acted upon. The chief point to be attended to is the selection of such containing vessels as are not injuriously affected by the fused substances,—and which do not themselves react upon their contents.

The implements for fusion are called *crucibles*, the smaller of which, for the less refractory substances, may be heated over the GAS or SPIRIT LAMP. To effect the liquefaction of bodies diffi-

cultly fusible, or of large quantities of matter, a FURNACE is requisite.

The size of the crucible should be proportional to the quantity of matter to be heated in it. It is best that its capacity should be no greater than sufficient for the contained substance with enough margin to allow for swelling or foaming.

CRUCIBLES.—A crucible, to be available for any and every operation, should possess the quality of compactness, in order to resist the corrosive action of fused substances, the permeability of gases and liquids, the fusing power of intense heat, and the tendency to fracture by sudden changes of temperature.

It is impossible to combine all these requisites in any one kind of crucible.

The materials of which crucibles are formed are either *pure* clay, or clay mixed with charcoal, quartz, graphite, or coke, to render it more refractory. Black lead, porcelain, silver, and platinum, have each and all their appropriate application.

Clay Crucibles.—The Hessian and French crucibles are those of this description, which are most used. The Hessian, so called from the place of their manufacture in Germany, are either in the form of a tapering cylinder or triangular, and are that kind of crucible most commonly found in our drug shops. They are met with in nests of a half dozen or more, gradually increasing in size from the smallest (of an ounce) to the largest, of pint or quart capacity.

Fig. 204.

They are grayish yellow or whitish, rough to the touch, and should give a clear ring when held by the bottom and sounded on the sides. Being hard and impermeable, they are very useful for rough fusions; but the silica which they contain renders them unfit for metallic oxides, with which at high heat it combines.

The Hessian crucibles require careful usage, as they are liable to be fractured by even slight changes of temperature. Therefore, notwithstanding their great cheapness, the London or French crucibles are more preferable for nice operations.

The London crucibles are very refractory, regularly formed, with smooth surfaces, and will endure a very high heat.

The French crucibles, Fig. 205, which are manufactured by

Beaufaye, of Paris, are said to be far superior to either of the preceding. They are whitish, well shaped, and smooth throughout, and being nearly free from oxide of iron, and less rich in silica, are applicable for the fusion of nearly all substances except certain salts, which, owing to the porosity of the crucible material, are readily absorbed.

Fig. 205.

Being capable of supporting extreme heat as well as sudden changes of temperature, they are very useful for the reduction of oxides and fusion of metals. Borax, glass, and similar substances, remain perfectly colorless when melted in these crucibles.

The mixture of graphite or coke with the clay, which is found in those of Austin's make, renders them capable of better supporting the softening influence of the wind furnace and withstanding the most sudden changes of temperature, but the proportion of the latter must not exceed 33 per cent., otherwise its combustion by the fire will leave the crucible porous and fragile.

As metallic oxides are reducible when hot, by contact with carbonaceous matter, these crucibles, when used for heating those substances, should be lined with a thick coat of clay paste and dried.

Charcoal is the only proper fuel for earthen crucibles, as coke is apt to form scoriæ, which attach to the crucible and impede the draught.

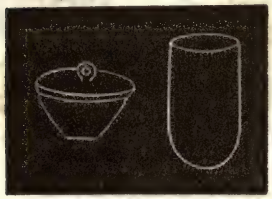
Black Lead Crucibles. Blue Pots.—Black lead or plumbago, when mixed with one-fourth of its weight of refractory clay, becomes capable of supporting intense heat and sudden changes of temperature. The chief use of crucibles made of this substance is in metallurgy, for the purposes of which their smooth surface admirably adapts them. They are not sufficiently compact for the fusion of salts.

Porcelain Crucibles.—Crucibles of this material are very neat implements, but by reason of their incapability of resisting even slight changes of temperature, are only used for purposes to which those of more refractory material are for other reasons not adapted. For heating over the lamp they must be small and thin. In analytic and nice operations they replace platinum in

many processes in which the contents act upon that metal, for example, in igniting plumbic precipitates, melting metallic oxides with sulphobases, preparing enamels, and heating metallic oxides, which are reduced easily in contact with platinum.

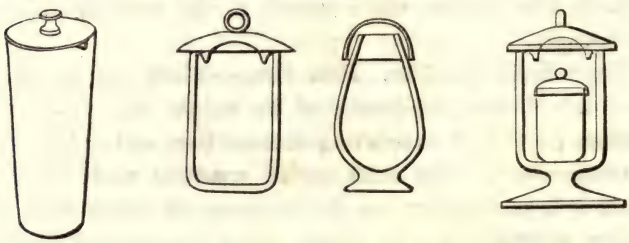
The crucibles, Figs. 206, 207, used directly over the lamp, should never exceed an ounce or two in capacity, for even with the most careful management it will be difficult to cool one of larger size gradually enough to prevent its breaking. Berzelius recommends their insertion in platinum crucibles as a means of diminishing their fragility. The French porcelain being very thin and light, and a better supporter of sudden changes of heat, is preferable to the Berlin for small crucibles.

Fig. 206. Fig. 207.



The impermeability and cleanliness of these crucibles, render them very convenient for the fusion of certain nice substances, such as nitrate of silver, potassa, &c., in large quantities, and as it is impracticable to have a very large platinum crucible in private laboratories, one of porcelain is substituted. These large crucibles, made with covers, may be of either of the forms, Figs. 208, 209, 210, and of Berlin porcelain, which is similar to Wedgwood-ware, and heavier and cheaper than the French.

Fig. 208. Fig. 209. Fig. 210. Fig. 211.



The large crucibles, varying in size from two to six inches in height, and from one to four inches in diameter, may be entirely biscuit, or else glazed only internally, and if heated over the fire require to be enclosed in a refractory fire-clay case, as shown in Fig. 211. This case is equally useful for platinum or silver crucibles (Figs. 214, 215), as it gives them a proper elevation above the grate, and prevents contact with the coals.

For the heating of more readily fusible substances they may be imbedded in a sand-bath and heated up gradually. If allowed to remain in the bath until it has cooled, the liability of fracture from sudden refrigeration will be diminished.

Some of the crucibles have duplicate covers, one of which is perforated and used to facilitate the escape of the gaseous matter generated during certain processes.

Metallic Crucibles.—Cast and plate iron, silver, and platinum, are all used as materials for crucibles.

Iron Crucibles.—For the fusion of silicates and certain seleniurets, sulphurets, and other substances, iron crucibles are very convenient. An exterior coating of clay is requisite to protect them from the oxidizing action of the air, to which they are subjected at high temperatures. The same object may be effected by inserting them in clay crucibles. When, however, the heating is not of long duration nor intense, they may be used naked.

Those of wrought iron, Fig. 212, are struck up from a single piece of thick sheet metal.

Fig. 212.

Fig. 213.

Cast-iron crucibles, Fig. 213, are cheaper, and equally as good as wrought iron for medium temperatures, but they must be turned smooth interiorly.

As some of the constituents of stove coal exert a chemical action upon metal, the only proper fuel is charcoal, when furnaces are used for heating the crucibles.

Silver Crucibles.—Silver crucibles are but rarely used, save for the fusion of potassa, soda, and for the preparation of caustic baryta from the nitrate. For most operations they are well replaced by platinum. For acid substances their use is improper. The spirit or gas lamp is the heating apparatus, but the heat must

not be too high nor of too long duration, for the silver is apt to become brittle in spots as it assumes a crystalline form under the influence of long-continued red heat.

Platinum Crucibles.—Platinum crucibles are of more general application than those of any other material. They are very tough and infusible at any heat that can be obtained from the gas or spirit lamp, the almost exclusive means employed for that purpose. As they are liable to become rough at high furnace temperatures, they should, when exposed to such influences, be inserted in an earthen crucible, and surrounded by a bed of magnesia.

Their strong resistance to the action of chemical reagents renders them indispensable in many operations, which it would be difficult otherwise to perform. They vary in size from a fluid-drachm to three or more fluid ounces capacity, the latter being as large as is necessary for any purpose in a private laboratory. Their form is shown in Figs. 214, 215.

Fig. 214.

The crucibles intended to be heated over the lamp must be of very thin metal, so that they can be weighed, as is often necessary, in a delicate balance. To give strength, however, the bottom must be thicker than the sides. Two of the smaller size will be found more useful than one of the larger. In analysis a half ounce crucible is indispensable for the IGNITION of filters.

The cover is, as seen in the figure, slightly convex exteriorly, and ledged around the circumference: this form is convenient when the vessel is to be entirely closed when heated; but in certain operations in the wet way it is reversed, so that the convex side may rest inwardly and return any particles of its contents that may be projected upwards, by a too sudden or intense elevation of temperature. The pin running through its centre is the knob by which it is handled, when cold with the fingers, and when hot with the tongs, Figs. 149, 150.

Platinum crucibles are also made with covers, in the shape of capsules, as shown by Fig. 215. They are very convenient for small evaporations, and are at the same time made to fit closely or loosely to the body of the crucible, as may be desired.

Unless the crucibles are made of perfectly pure metal, and are

Fig. 215.

hammered out instead of being turned, their power of enduring strong heats and resisting the action of chemical reagents will be impaired. The blisters and flaws which appear, after use, are owing to impurity and bad workmanship, and are to be removed by the force of a small hammer.

When the crucible becomes cracked or perforated, it can be repaired by welding on a layer of platinum sponge, but it is far better to have it melted up and remodelled by a manufacturer.

Boiling or hot water loosens adherent saline matters, and fused borax or muriatic acid will remove all stains which do not disappear by rubbing with sand or pumice-stone. The use of sharp-pointed instruments will be apt to injure the crucible.

The experimenter himself can, in any emergency, readily form a crucible out of platinum foil by shaping it with the thumb or a small hammer, in a hemispherical cavity made for the purpose, in a wooden block.

Berzelius (*Traité de Chimie*, vol. viii) gives the following instructions as to the manner of using platinum crucibles.

"Dry fusion should never be effected in platinum crucibles: 1st. Caustic alkalies, nitrates of lime, baryta, or strontia, and alkaline nitrates, always attack the platinum. Alkaline sulphurets or sulphates with charcoal are still more injurious. Metals, when heated to their melting-points, alloy with it, and hence lead, tin, antimony, &c., should never be even moderately heated in it. Even their oxides, especially those of copper, lead, bismuth, and nickel, reduce at a high heat by contact with platinum, particularly if charcoal is present, the two former at a lower temperature than the latter. Gold, silver, copper, and others, can be reddened, but not melted in platinum. Phosphorus or phosphoric acid and carbon readily attack it. Sulphate of lead may be burned off in it with care, but for the chloride, porcelain should be used.

"Silica may be ignited in platinum, but it combines with silicium at a heat beyond redness, and therefore they should always be encased when heated in the fire, otherwise, if in contact, it will abstract it from the coals.

"Nearly all liquids may be heated in platinum, except they contain chlorine, bromine, iodine, or nitro-muriatic acid.

"For the fixed alkalies, gold is preferable to either silver or platinum, upon which they have a more or less corrosive action."

Directions for Heating Crucibles.—All the larger and coarser crucibles are heated in FURNACES. Their proper position is an upright one in the centre of the grate, upon a slight elevation. They should be warmed before being placed in the furnace, so as to prevent liability to crack by sudden heating. Ignited coals are then placed at the bottom of the grate and covered with alternate layers of unlit coke and charcoal, of nut size, until the crucible is surrounded up to the level of its top with fuel. When the crucible is to be strongly heated, it should be covered and the fuel heaped over its top. In all cases the fire must be gradually raised and steadily kept up, and the furnace only opened when fresh additions of coal are necessary, as it is important that there shall be no variation of temperature in its interior. The duration of the process, and the degree of heat employed, must depend upon the nature of the substance under process.

After the completion of the operation, the crucible should be allowed to cool with the furnace, or if taken out immediately, placed upon a brick or bed of warm sand, otherwise a too sudden change of temperature will cause its fracture. The furnace tongs, Fig. 148, are conveniently shaped for this purpose.

As it is occasionally necessary to poke the fire in order that the fuel may settle previous to fresh additions, it will be well to give the crucible a firm position upon a stand for the purpose,—the half of a fire-brick, for instance, so that in the settling of the coal, there may be no risk of its being upset. When by intense heat its bottom has become welded to the brick, the latter can very readily be detached by a gentle tap of the poker.

Most of the common crucibles serve only for a single operation.

Covers may be made by inverting a smaller crucible over the top; or better, by making a dough of Stourbridge clay, and luting it on. The crucible, in the latter case, must not be heated until the cover has dried. These lids have a tendency to retard volatilization, and are necessary to prevent the entrance of falling particles of coal and ashes. For the escape of gaseous

matter a small perforation in the centre of the cover is necessary, but in intensely hot fusions all other openings must be closed with LUTE.

The *smaller* metallic crucibles are almost exclusively heated over LAMPS. They are supported upon wrought iron rings, Figs. 179, 180, the diameter of which may be reduced when necessary, by the use of the wire triangles, Fig. 181, of the required size.

If the crucibles are very small they may be heated by the mouth blow-pipe. For the larger an Argand, spirit, or gas lamp, Fig. 165, is needed. To hasten the process or to increase the temperature, the table blow-pipe, Figs. 45, 164, is convenient, as it gives a powerful blast.

The use of the jacket, Fig. 156, is an additional means of still further economizing and increasing the power of the flame. It also diminishes the loss of heat from the crucible by radiation, especially when the latter is covered. In charging the crucibles, the contents should be concentrated into as small a space as possible, and any adherent particles should be brushed from the sides with a feather. When the crucibles are emptied of their fused contents, the melted matter may be made to flow upon a smooth and clean slab of marble, iron, or other proper material, —great care being taken that it does not come in contact with any moisture or damp substance.

Fusion of Substances unalterable by Heat or Air.—This class comprises a very large number of substances, among which are the noble metals, &c. The crucible employed should be kept covered as well whilst cooling as heating, and the refrigeration must be gradual, or the molten matter may spirt. There are other metals again, for instance, zinc, lead, tin, antimony, and bismuth, which, at high temperatures, oxidize readily upon exposure. In such cases it is well, in addition to keeping the vessel closed, to cover the fluid mass with a layer of powdered charcoal.

When a metal is in process of fusion it is imprudent to make fresh additions without having first heated the material to be added, for the sudden entrance of cold or damp matter into the hot fluid mass will cause the ejection of particles, and perhaps serious inconvenience.

In the manufacture of alloys the metals should be well incorporated by occasional stirring. When iron, and indeed manganese, cobalt, nickel, and chrome, are being exposed to high degrees of heat, the crucibles must be free from carbonaceous matter, otherwise a combination may ensue at high temperatures.

Fusion of Substances alterable by Heat.—For the treatment of substances which melt below 212° F., the water-bath is convenient. The fusion of substances, such as wax, resin, and fat, immiscible with that liquid, may be facilitated by the direct application of boiling water, as they can be readily removed from the surface, to which they rise, with a ladle or syphon whilst hot, or in a mass if allowed to cool.

Substances requiring a temperature at or below 550° for their fusion, may be melted in an oil-bath.

Alloys containing volatile metals should be heated as quickly as possible.

Certain substances which volatilize at low temperatures require to be fused in closed vessels. Iodine and arsenic are examples.

A tube of glass, porcelain, or metal, according to the nature of the substance, is the best form of apparatus for this purpose. It should be rounded at one end, and after the introduction of the substance, closed at the other over the blow-pipe. The tube must be heated throughout its length.

Fusion of Bodies alterable by Air.—This class of substances is melted in seclusion, the air being shut out by means of an intermedium of liquid, powder, or fusible matter. Thus potassium is liquefied under naphtha, phosphorus under water, and certain other substances in powdered charcoal.

The covers of the crucibles in these cases must be tightly luted, so that all openings may be closed.

Fusion of difficultly fusible Substances.—All substances which resist the fusing power of furnaces, are to be subjected to the more intense action of the HYDRO-OXYGEN BLOW-PIPE, or Bunsen's battery. One or other of these latter means will prove effective, in all possible cases.

Fusing-points.—The usual mode of determining the point at which a substance fuses, is to place a thermometer in it whilst fluid, and note the degree at which solidification ensues. There

are, however, according to Brodie (Mechanic's Magazine, 1854), some substances whose points of fusion so closely approximate the degree at which they assume allatropic conditions, that they require a modification of the above plan, for such change of state is always accompanied with evolution or absorption of heat. In these cases the substance is to be divided into small particles, placed in a thin glass tube, when its melting-point is below that of glass, and immersed in a bath of boiling dilute sulphuric acid or other suitable liquid. At the moment the contents of the tube melts, the temperature of the bath is to be noted by a thermometer, and recorded as the fusing-point of the substance under experiment.

CHAPTER XV.

IGNITION.

SUBSTANCES frequently require to be ignited to redness, either as the sole process of their preparation, or as a preliminary step to subsequent operations.

Ignition of Filters.—In analyses, the filters containing the insoluble or precipitated substances which are to be estimated are ignited or "burned off," to expel carbonaceous and volatile matters before being weighed. The implements for this purpose are porcelain or platinum crucibles, either having their appropriate applications.

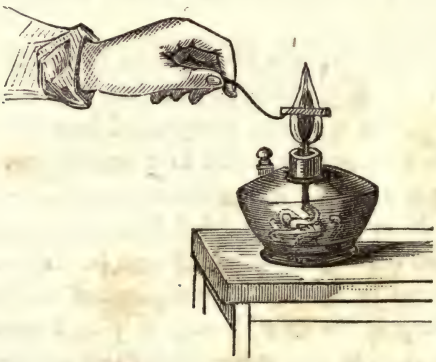
As it is necessary that the filter should be wholly or partially dry, it must be carefully removed from the funnel, so as not to lose a particle of its contents, compressed between the folds of bibulous paper, and, further, dried in a capsule over a sand or water bath, or in a drying stove (DESICCATION), at a temperature of about 200° F. or less. The dried filter and contents are then to be transferred to the crucible, which must be previously weighed. The transfer must be made without the loss of the least particle, and for this purpose the crucible may be placed upon a sheet of glazed white paper, so that any particles that accidentally fall in the act of emptying the filter may be preserved. The filter, after having been freed as much as possible from the adherent

precipitate by gently rubbing the sides together between the thumb and forefinger, is finally placed in the crucible with its contents—being folded loosely and laid at the top. The force used for this purpose must not be sufficient to abrade the paper, otherwise the matter will reach the fingers, and a loss thus be occasioned by adherence. The crucible is then heated cautiously and gradually over the spirit or gas lamp, Fig. 141, the flame of which may be urged by the blast. For the first few moments the vessel should remain covered, for fear of loss by decrepitation, but as soon as it becomes red hot the lid may be wholly or partially removed, and the crucible inclined, as at Fig. 216. This position promotes free draught and the complete and rapid incineration of the filter. This being done, the cover is replaced, the crucible allowed to cool, and then weighed. The weight of the crucible and that of the ashes of the filter, which latter has been previously determined by the incineration of filters of different sizes, deducted from the total weight, gives the weight of the ignited precipitate.

Fig. 216.

The above directions apply to precipitates which are not alterable by being burned with the filter. When, however, the matter is preserved free of ashes for use or further examination, or is liable to be reduced or otherwise changed by the carbon of the filter, the latter and its contents must be ignited separately. In

Fig. 217.



such cases, the drying of the filter and the detaching of its contents are accomplished as already explained. The contents are

heated in a platinum crucible as usual, but the empty filter, after having been freed as much as possible from adhering particles of the dry contents, is incinerated in another way, originally suggested by Bunsen. The necessary manipulation consists in placing the filter upon a sheet of white paper, doubling over its circumference first at the sides and then at the ends, so as to guard against the possibility of any loss of matter, and finally rolling it up into a tight cylinder. This cylinder is next tightly wrapped with one end of a platinum wire, and held over the flame of an alcohol lamp, as shown by the drawing, until the filter has become thoroughly incinerated. The original volume of the filter having, of course, largely contracted, from loss of matter by the heating, it will easily fall from its position in the platinum wire-coil holder, when the latter is held over the crucible or its capsule cover, accordingly as it may be desirable to weigh the filter ash portion and the pure precipitate jointly or separately.

The greatest possible care must be observed in analytical experiments to prevent the least loss of the precipitate. The crucible must, moreover, in all cases, be cooled under a bell wherein is a vessel containing some hygroscopic substance, so as to provide against error from absorption of moisture previous to the weighing.

When substances are to be ignited for the determination of their hygroscopic, volatile, or organic matter, heat should be very gradually applied, without the blast, and to a limited degree. In these instances, the crucible should be weighed first, so that the loss sustained by a given weight of its contents, during ignition, may be ascertained in one weighing, merely by subtracting the weight of the crucible and contents after ignition from the combined weight of the two before the same process. The loss gives the amount of volatile matter.

In analyses of coals, the moisture can be determined by heating the crucible in a hot sand-bath, or very gently over a low flame. After the loss thus occasioned is determined by weighing, the amount of carbon may be ascertained by subjecting the crucible and contents to a much higher heat.

When substances are to be exposed to heat, the crucible and contents must likewise be weighed separately before ignition.

The loss of weight gives the amount of volatile matter driven off. The ignited matter can then be removed from the crucible by hot water alone or acidulated.

Scoriæ may be removed from platinum crucibles by covering them with a paste of borax and carbonate of soda, heating them to redness, and when cold, dissolving out the saline matter with boiling water. A repetition of the process is necessary to brighten the crucible perfectly if it had been very dirty.

Ignition of Bodies in Vapors.—If it be desired to heat a fixed substance in the vapor of any body, which is solid or liquid at ordinary temperatures, the latter may be put into a tube closed at one end, or into a small flask with a long neck, and then be heated until it is wholly vaporized. The substance is to be introduced into the tube, and heated in the vapor at any desired temperature. Thus, to show the affinity of sulphur for copper, the former is heated until its vapor fills the whole flask, when slips of copper foil let down into it immediately ignite on combining with the sulphur. When a tube is used it may be held in any inclined position, but a flask should be nearly vertical.

Ignition with Fluxes.—Fluxes are certain substances, usually saline, mixed with other bodies in order to promote their fusion or decomposition by heat, and to render them more soluble in water and acids. All ignitions with fluxes in experimental operations are performed in crucibles over the spirit-lamp or furnace fire, and for the fluxions of those substances in which there is no reducible metallic oxide, platinum is by far the best material.

The process is particularly useful in analysis of the sulphurets, of alkaline earths, of many silicates, and other obstinate compounds, and also in metallic operations.

The principal objects of fluxing are:—

"1. To cause the fusion of a body, either difficultly fusible, or infusible by itself.

"2. To fuse foreign substances mixed with a metal, in order to separate the latter by its difference of specific gravity.

"3. To destroy a compound into which an oxide enters, and which prevents the oxide being reduced by charcoal. The silicate of zinc, for instance, yields no metallic zinc with charcoal, unless it be mixed with a flux capable of combining with the silica.

"4. To prevent the formation of certain alloys, and consequently the combination of some metals with others, as in the case of a mixture of the oxides of manganese and iron with a suitable flux, the iron is obtained in a state of purity, whereas if no flux had been added, an alloy would have been obtained. Gold and silver can be separated from many other metals by means of a flux.

"5. To scorify some of the metals contained in the substance to be assayed, and obtain the others alloyed with a metal contained in the flux, as gold or silver with lead.

"6. And lastly, a flux may be employed to obtain a single button of metal, which otherwise would be obtained in globules."

Fluxes, as well as the substances to be fluxed, must be reduced to the finest state of comminution previous to mixture.

When the mixture is of a frothing nature, it is best to add it to the crucible piecemeal, and to heat it gradually, so as to save the loss caused by ejection of particles. After the whole has been placed in the crucible, the heat may be raised and maintained until perfect fusion and the completion of the process.

The mixing of the charge is done with glass rods or platinum wires, and the containing crucible must be of sufficient capacity to prevent loss by the ejection of particles. The flux should be rather in excess. In the fluxing of substances which evolve gases, the cover of the crucible should be laid on loosely; but in those experiments requiring the use of a furnace, the crucible must be close and tight. The Russian or other similar lamp will produce sufficient heat for ordinary fluxions; and Barron's furnace will serve for the more refractory. When a platinum crucible is heated in a blast or common furnace, it should be imbedded in a Hessian or iron crucible lined with magnesia, otherwise it will be damaged.

Fluxes are divided into non-metallic and metallic fluxes.

NON-METALLIC FLUXES.—(Berthier, *Essais par la voie Sèche.*) —*Silica* is employed frequently to cause the fusion of some gangues in assays made at an elevated temperature. Silica combines with all the bases, and forms with them bodies termed silicates, which are more or less fusible.

Lime, Magnesia, and Alumina.—It is known that no simple silicate is readily fusible, so that lime, magnesia, or alumina are

employed, according to circumstances, to reduce a simple silicate to such a condition that it will readily fuse in an assay furnace. Sometimes, to attain this end, it is requisite to use all the above-mentioned earths, for experience has proved that, as a general thing, a mixed or double silicate fuses more readily and flows freer than a simple silicate.

Baryta.—Hydrate of baryta fuses at a low red heat, and without loss of its water of crystallization, and for the first reason is preferable to either the carbonate or nitrate. It is used in silver or platinum crucibles, and when silicates are to be tested for alkalies. The silicates of baryta, however, fuse with difficulty, and are sluggish.

Glass is a very useful flux in certain iron assays. The kind employed must not contain lead.

Boracic Acid.—The native boracic acid, after fusion and pulverization, is to be employed whenever the use of this acid is indicated. It ought to be kept in well-stoppered bottles.

Boracic acid has the property of forming with silica and all the bases very fusible compounds, and is from this cause a very universal flux. Nevertheless, there is an inconvenience attached to its use; it is very volatile, so that sometimes the greater part employed in an assay sublimes before it has had time to perform its office.

Borax (*Biborate of Soda*) is an excellent and nearly universal flux, because it has the property of forming, like boracic acid, fusible compounds with silica and nearly all the bases, and is preferable to that acid because it is much less volatile.

It may be used at a high or low temperature. In the first case, it is employed in the assay of gold and silver, because it fuses and combines with most metallic oxides, or in obtaining a *regulus*, that is to say, to separate the metals, their arseniurets and sulphurets, from any stony matter with which they may be mixed, because this salt is neither oxidizing nor desulphurizing. In the second place, it is employed in the assay of iron and tin ores, as in the presence of charcoal it retains but traces of their oxides, and, indeed, much less than generally remains with the silicates.

When borax is heated it fuses in its water of crystallization, and undergoes an enormous increase of volume; at a higher tem-

perature, it fuses and forms a transparent glass, which becomes dull on the surface by exposure to air. Only the fused vitrified borax ought to be used in assays. It must be reduced to powder, and kept in well-closed vessels.

Fluor Spar (*Fluoride of Calcium*) is rarely employed in assays, but in certain cases is an excellent flux, especially where sulphates are present, with many of which it forms very fusible compounds. The best proportions are about equal equivalents of the spar and the anhydrous sulphates of alkali, lime, and oxide of lead; but for the sulphate of baryta, two eqs. of the spar for one eq. of the sulphate.

It likewise assists in fluxing silicates, partly by direct union with them, and partly by yielding fluosilicic gas, and leaving lime to unite with silica.

Carbonate of Potash and Carbonate of Soda.—It has been already proved that they possess oxidizing and desulphurizing power; they will now be considered as fluxes.

They are decomposed in the dry way by silica and the silicates, with the separation of carbonic acid. The presence of charcoal much facilitates this decomposition.

The silicates of potassa and soda fuse readily and flow freely.

They form fusible compounds with the greater part of the metallic oxides; in these combinations the oxide replaces a certain quantity of carbonic acid; but these compounds are not stable,—they are decomposed by carbon, which reduces the oxide, or by water, which dissolves the alkali.

On account of their great fusibility, the alkaline carbonates can retain in suspension, without losing their fluidity, a large proportion of pulverized infusible substances, as an earth, charcoal, &c.

The alkaline carbonates ought to be deprived of their water of crystallization for assaying purposes; in fact, it would be better to fuse them before use. They must, in all cases, be kept in well-stoppered vessels.

They may be used indifferently, but carbonate of soda is to be preferred, as it does not deliquesce.

A mixture of both is far preferable to either alone, and, moreover, requires a lower heat for its fusion. The proper proportions are ten parts of effloresced carbonate of soda and thirteen

parts of dry carbonate of potassa. The two are to be intimately incorporated by trituration, and the mixture kept in stoppered bottles. This flux is the one of most general application.

The alkaline carbonates of commerce always contain sulphates and chlorides. In ordinary cases, this causes no inconvenience, but there are circumstances under which the presence of sulphuric acid would be injurious.

Carbonate of potash can readily be procured free from sulphate and chloride by means of nitre and charcoal, as follows:—Pulverize roughly 6 parts of pure nitre, and mix them with 1 part of charcoal; then project the mixture spoonful by spoonful into a red-hot iron crucible. The projection of each spoonful is accompanied by a vivid deflagration, and carbonate of potash is found in a fused state at the bottom of the crucible; it must be pulverized, separated from excess of charcoal, and kept in a dry state for use.

Carbonate of soda may be obtained in much the same way, by substituting nitrate of soda for nitrate of potash; or by repeatedly crystallizing the carbonate of commerce.

Nitrate of Potash.—The presence of silica or silicates much assists its decomposition. It is used as an oxidizing agent, the potash resulting from its decomposition acting as flux. To prevent violent action and ejection of particles of matter, its addition to the crucible must be careful and gradual. Nitre is also employed in some instances as a substitute for nitrate of ammonia for effecting the rapid and perfect combustion of organic substances.

Common Salt (*Chloride of Sodium*) was much recommended by the older assayers, either mixed with flux, or a certain quantity placed above it, for the purpose of preserving the substances beneath from the action of the atmosphere, or to temper the action of such bodies as cause much intumescence. It is very useful in lead assays. When it is used, it must be previously pounded and heated to dull redness in a crucible to prevent its decrepitation.

Black Flux and its Equivalents.—Black flux is both a reducing and a fusing agent. It is a mixture of carbonate of potash and charcoal in a minute state of division. It is much employed, and very serviceable. It is prepared by mixing 2 parts of argol

with 1 part of nitre, placing the mixture in an iron vessel and setting it on fire by a burning coal or red-hot rod. When the combustion is finished, the substance is pulverized and sifted whilst yet hot, and kept in well-stoppered jars, as it rapidly absorbs moisture from the atmosphere.

Black flux is much used in lead and copper assays; but as it swells greatly at the commencement of the operation, the crucible must not be more than two-thirds full.

It can be readily imagined that, as it fuses and reduces at the same time, the relative proportions of alkali, carbonate, and charcoal ought to vary according to the nature of the substance acted upon; and it is often expedient to employ the greatest possible proportion of alkali to obtain the largest yield of metal. Black flux may be obtained richer in carbon by mixing 1 part of nitre with 2½ or three parts of argol.

Common black flux contains 5 per cent, of charcoal. The flux prepared with 2½ of tartar or argol to 1 of nitre, contains 8 per cent., and that with 3 contains 12 per cent. of charcoal.

Black flux can be replaced by anhydrous or dry carbonate of soda mixed with some reducing agent. When charcoal is employed it must be reduced to a very fine powder; in fact, it ought to be levigated.

The three following fluxes are very useful:

Carbonate of Soda,	94	88	816
Charcoal,	6	12	184

The second is very nearly equivalent to sodium and carbonic acid, and the third to sodium and carbonic oxide; but it must be observed, that whatever precautions be taken, these mixtures never become so liquid as black flux, because the charcoal tends very much to separate and rise to the surface.

Instead of charcoal, it is preferable to use sugar or starch to make a flux equivalent to black flux with carbonate of soda; the mixture must be made most intimately.

Cream of tartar, carbonized by a semi-combustion until it is reduced to half its weight, is a very good substitute for black flux: it contains about 10 per cent. of charcoal.

Argol (*Cream of Tartar, Bitartrate of Potassa*).—When bitartrate of potassa is heated in a covered crucible, a rapid decomposition takes place, accompanied by a disengagement of in-

flammable gases; the substance agglomerates, but without fusing or boiling up. The residue is black, blebby, and friable, and contains 15 per cent. of carbon when produced from rough tartar or argol, and 7 per cent. from cream of tartar.

These reagents produce the same effects as black flux, and possess more reducing power, because they contain more combustible matter; but this is an inconvenience, because the excess prevents their entering into full fusion when the substance to be assayed requires but a small proportion of a reducing agent. They can be used with success in assays requiring much carbonaceous matter.

Bisulphate of Potassa is a convenient flux for several minerals, such as for those highly aluminous (*Rose*), for chromic and other similar ores (*Booth*).

Salt of Sorrel (*Binoxalate of Potassa*), when heated, is decomposed. It decrepitates feebly, and during its decomposition is covered with a blue flame; it at first softens, and when fully fused, is wholly converted into carbonate. When the oxalate is very pure, the resulting carbonate is perfectly white and free from charcoal; but very often it is spotted with blackish marks. It has no very great reducing power.

Cyanide of Potassium acts powerfully both as a reducing and desulphurizing reagent, and is a very useful flux in small assays. According to Liebig it has the advantage over the potassa salts with vegetable acids, of not carbonizing the metal, for the salt changes at the expense of the metallic oxide into cyanate of potassa. If the metallic oxide predominates, the rest will be reduced by the cyanic acid without separation of carbon.

White, or Mottled Soap is a compound of soda with a fat acid. When heated in close vessels it fuses, boiling up considerably, and during its decomposition gives off smoke and combustible gases, and leaves a residue composed of carbonate of soda with about 5 per cent. of charcoal. Of all reducing agents soap absorbs the greatest quantity of oxygen, and as the residue of its decomposition by heat affords but little charcoal, it has the property of forming very fluid slags. Nevertheless, it is rarely employed, because certain inconveniences outweigh its advantages. These inconveniences are, its bubbling up and its extreme lightness. It also requires to be rasped, in order to mix it perfectly

with the substances it is to decompose, and it then occupies a very large volume, and requires correspondingly large crucibles. There are nevertheless cases where it may be used with advantage by mixing it with other fluxes.

All those fluxes containing alkaline and carbonaceous substances are reducing and desulphurizing, besides acting as fluxes, properly so called; they also produce another effect which it is useful to know, viz.: they have the property of introducing a certain quantity of potassium or sodium into the reduced metal. This was first pointed out by M. Vauquelin.* He found that when oxide of antimony, bismuth, or lead was fused with an excess of tartar, the resulting metals possessed some peculiar characters, which they owed to the presence of several per cent. of potassium.

METALLIC FLUXES.—*Litharge and Ceruse.*—These bodies always act as fluxes, but at the same time often produce an alloy with the metal contained in the ore to be assayed. Ceruse produces the same fluxing effect as litharge. The litharge is the better flux, and is very useful in a great number of assays.

It fuses readily with the oxides of iron, copper, bismuth, antimony, and arsenic, sulphate of lead and the silicates, in the proportion of 2 to 5 parts of litharge to 1 part of the substance to be fluxed; other oxides require a larger amount of litharge. Its action is that of promoting fusion, reducing an oxide, and desulphurizing a sulphuret.

Glass of Lead (*Silicate of Lead*).—The silicates of lead are preferable to litharge in the treatment of substances containing no silica, or which contain earths or oxides not capable of forming a compound with the oxide of lead, excepting by the aid of silica. It may be made by fusing 1 part of sand with 4 parts of litharge; if required more fusible, a larger proportion of litharge must be added.

Borates of Lead.—The borates of lead are better fluxes than the silicates when the substance to be assayed contains free earths; but in order to prevent them swelling up much when fused, they must contain an excess of oxide of lead. The borate of lead containing ·9056 of oxide of lead, and ·0944 of boracic

* Annales des Mines.

acid, is very good. Instead of borate of lead, a mixture of fused borax and litharge may be employed; it is equally serviceable.

Sulphate of Lead is decomposed by all silicious matters and by lime, so that when these substances are present litharge is produced, which fluxes them.

Oxide of Copper is rarely used as a flux for oxidated matters, but is sometimes employed in the assays of gold and zinc to form an alloy with those metals. In this case a reducing flux must be mixed with the oxide. Metallic copper may be used, but is not so useful, as it cannot be so intimately mixed with the assay.

Oxides of Iron are good fluxes for the silicates. They are, however, rarely employed for that purpose; they are more often used to introduce metallic iron into an alloy to collect an infusible or nearly infusible metal, by alloying it with iron, such as manganese, tungsten, or molybdenum.

CALCINATION.—The separation (in a dry way) of volatile from fixed matter, by heat, is termed calcination. The process is applicable

To the expulsion of water from salts, minerals, coals, and other substances.

" " carbonic acid from certain carbonates.

" " arsenic and sulphur from cobalt, nickel, and other sulphuretted compounds.

" " bituminous matter from coals, and certain minerals and ores.

To the ignition of quartz and silicious minerals to promote their disintegration.

For the purpose of expelling the combined water of argillaceous minerals, and of thus rendering them more obstinate to the solvent action of acids and reagents.

If the substance under process is organic, its calcination in a close vessel by a medium heat usually effects only partial decomposition, the gaseous matter generated escaping through interstices, and the fixed components remaining with a portion of unaltered carbon. Performed in this manner, the process takes the name of *coking*, familiar instances of which are the formation of coke by distilling coal in closed retorts, the manufacture of charcoal from wood, and of bone black from bones.

By increasing the temperature and admitting the air, the *whole*

of the alterable and volatile matter is expelled, the fixed matter remaining as ashes. The process is then styled *incineration*, and in this way the coke, charcoal, and ivory black, obtained as above directed, may be entirely reduced to their incombustible portions or ashes.

Calcination is effected in platinum spoons or crucibles, in delicate experiments, over a spirit-lamp; but in large operations a furnace is required, and the containing vessels are crucibles, of either metal or earthenware, according to the nature of the substance to be heated, though the latter are often unsuitable for temperatures above a red heat.

When the operation is finished, the crucible should be taken from the fire and allowed to cool gradually. The cover is then to be lifted off, and the contents taken out with a spatula, and the portions adhering to the sides removed with a feather.

If the substance undergoing calcination is fusible, it is necessary, when quantities are to be ascertained, to weigh both the crucible and contents before ignition, so that the amount of volatile matter driven off may be expressed by the weight lost in heating. Water alone, or acidulated, with the aid of heat, generally removes the calcined matter from the crucible.

A body decrepitating by heat should be powdered before being subjected to the process of calcination, and the temperature should be raised slowly and gradually, otherwise when the crucible is not covered, a loss may result from the ejection of particles.

To avoid contact with the generated vapors or with the atmosphere, which to some substances act as reducing agents, the crucible should in such cases be covered, and, if tightly luted, perforated with one or more small holes for the escape of vapor.

ROASTING.—This process, as generally understood, is a kind of calcination to which many ores are submitted before their final reduction to the metallic state, for the purpose of expelling ingredients which would either delay that process or be injurious to the metal when extracted. In this way, water, carbonic acid, sulphur, selenium, arsenic, and sometimes other substances, are driven off from the ores containing them. The term is also applied to other processes, among the most important of which is that of the exposure to heat and air, by which metals become

altered in composition. Thus, copper becomes oxidized, and antimony and arsenic acidified by union with oxygen.

Roasting is always effected in broad, shallow open vessels, so that the air may have free access; and in order to promote the absorption of oxygen or the escape of the volatile substance, the surface of the body to be heated should be increased by previous pulverization, and it should be constantly stirred during the operation, so as to present as many points of contact as possible. The most suitable vessel is a baked earthenware saucer or capsule placed in a muffle or upon the bars of a calcining furnace. Sometimes a crucible is used, and then the position of the vessel in the furnace should be slightly inclined on one side. In either case the vessels should be heated to dull redness previous to receiving their charge.

That species of roasting termed *deflagration* is effected by rapidly heating the substance to be oxidized, together with some additional body as an oxidizing agent, as a nitrate or chlorate, for instance. The powdered mixture is added portionwise to the crucible previously heated, and maintained at redness during the operation. The vivid and sudden combustion which ensues modifies the composition of the original substance, and increases its amount of oxygen at the expense of the addendum. Thus, for instance, sulphuret of arsenic is deflagrated with nitre, to produce arseniate of potassa, titanium; and certain other metals to be transformed into oxides.

Deflagration is also used as a means of detecting the presence of nitric or chloric acids. For this purpose the suspected substance is to be heated with cyanide of potassium, in a small platinum spoon. If deflagration ensues, it is a test of the presence of one of them, or a compound of one of them.

The crucibles may be of clay or metal, according to the nature of the substance to be heated. The roasting of substances for the expulsion of organic matter may be effected in platinum vessels, provided the heat is not carried sufficiently high to produce fusion of the substance being roasted.

The heat must, at first, be very gradually applied, and at no time be made great enough to fuse or agglutinate the material, otherwise the process will have to be suspended in order to repulverize the matter. Proper care at the commencement will

obviate the necessity of this additional trouble. When the heat has been cautiously raised to redness and all liability of fusion is over, the fire may be urged to the production of a yellowish red or even white heat, so that the expulsion of volatile matter may be complete.

Roasting operations which disengage deleterious or disagreeable fumes should be carried on in the open air or under a hood, and when the volatile matters are valuable, they may be condensed as directed in DISTILLATION and SUBLIMATION.

Decrepitation, which frequently occurs and occasions loss by ejection of particles of the mixture, is owing to the sudden vaporization of the water of crystallization, or water mechanically confined, which in finding vent scatters the confining substance with a crackling noise. To prevent this loss, the crucible should be loosely covered until decrepitation ceases.

REDUCTION.—This operation illustrates the use of tubes in experiments requiring the application of high heat. It is employed for the separation of metallic bases from any bodies with which they are combined; but is generally confined to the extraction from an oxide—that being the kind of combination most commonly met with. The combined action of heat and certain reagents is required to effect this result, the temperature varying with the nature of the substance to be reduced.

The most usual reducing agents are charcoal and hydrogen gas. Tallow, oil, and resin are sometimes used, but being easily decomposed they are dissipated before entire reduction has occurred. Sugar and starch are also occasionally employed. We shall, however, confine our remarks to the two principal articles.

Reduction by Charcoal.—Charcoal is used for this purpose in two ways, either in powder and directly mixed with the substance, or as a lining coat to the crucible in which the reduction is accomplished. The first mode is objectionable, because the excess of coal which is required to be used interferes with the agglomeration of the particles of reduced metal. Whenever it is adopted, the quantity of coal-dust to be added, which must be sufficient to transform all the oxygen of the oxide into carbonic acid, can be determined by calculation. This amount is then mixed thoroughly with the oxide previously powdered, and is transferred to a cru-

cible, taking care to place the charge in the centre, and to cover the contents with a layer of the dust. The whole is then to be subjected to the heat of a furnace, assisted if necessary, by a blast. The reduction in this way, the most convenient for large quantities, is rapid and complete, but the metallic residue is often mixed with coal-dust.

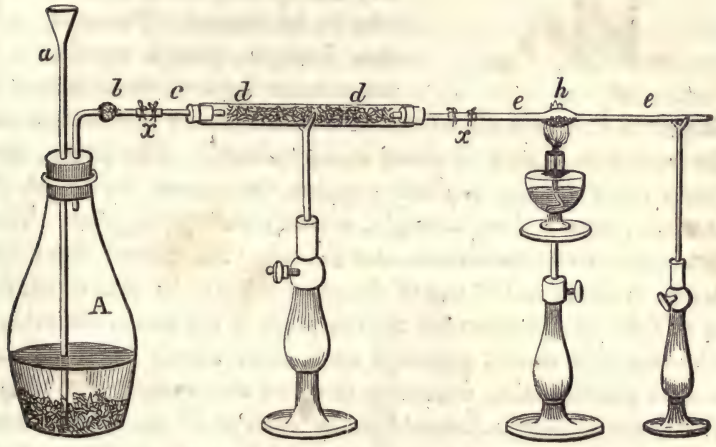
In general, the mere contact of carbon is sufficient to effect reduction, and consequently the inconvenience of the above plan may be avoided by the use of a brasque or crucible lined interiorly with charcoal. An earthen crucible is very readily brasqued as follows:—A mixture of three parts of charcoal-dust, and two parts of powdered clay, is mixed with water and kneaded into a plastic dough. The bottom of the crucible is then covered with this dough, and a wooden cylindrical core of diameter equal to that required for the cavity, is inserted in the centre and surrounded with more of the same dough, which is compressed with the fingers at each addition so as to make the whole as compact as possible. The core is then to be carefully withdrawn, and the crucible placed aside to dry. A platinum crucible, which is as applicable as clay for certain operations, can be brasqued in the same way. Some operators use the coal-dust without clay, and moisten it with water or oil. The crucibles should be free from external fissures to prevent access of air, and must always be covered when heated. The reduction by this plan is slower than by the first mode, and requires a higher temperature, but the metal as procured is cleaner.

The powdered oxide is placed in the cavity in sufficient quantity to fill it, then compressed with the fingers and covered with a layer of coal-dust. The cover being luted upon the crucible the whole is to be heated in a blast furnace. The reduction proceeds from the surface, that part of the oxide next to the charcoal being first acted upon. The time required depends upon the nature of the oxide, the degree of temperature, and the quantity under process; sometimes, particularly when the metals are very fusible, the reduced particles collect in a clean lump at the bottom of the crucible, and are easily removable when cold, with the finger or spatula. Others again, more refractory, form a very friable lump of metallic powder.

Reduction by Hydrogen.—This mode, which is much used in

analyses, consists in passing a current of hydrogen gas over the metallic oxides heated to redness in a glass, or better, porcelain tube, and is equally applicable to some chlorides and other compounds. The arrangement of the requisite apparatus is shown in Fig. 218. *A* is a flask for the disengagement of hydrogen

Fig. 218.

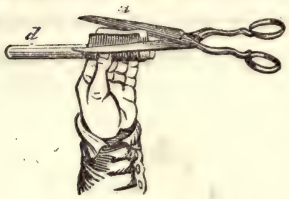


gas, by the action of dilute sulphuric acid upon zinc, the funnelled tube *a* being for the ingress of the acid. The disengagement tube *b* is bent at right angles and bulbed midway in its horizontal arm. The bulb is to be furnished with a plug of raw cotton for the condensation and retention of any aqueous vapor that may pass over. This tube is joined hermetically to another short tube *c* by means of an india-rubber connection.* The

* The use of india-rubber as a material for forming flexible joints is one of the most important aids in chemical manipulation. Its property of readily uniting at freshly cut surfaces, its flexibility, its ready and close adhesion to surfaces, and power of resisting the action of corrosive vapors, except those of chlorine, sulphuric and nitric acids, and a few others, render it peculiarly excellent for many mechanical purposes of the laboratory. Tubes of any shape and size, according to the form and dimensions of the parts of apparatus to be connected, are to be fashioned out of it with almost equal facility. For the transmission of corrosive vapors or gases they should have an outer layer, the seam in which must be directly opposite to that in the tube which it invests, so as to insure perfect tightness. Prof. Booth uses the india-rubber pipe, made by Goodyear, as conduits for steam in boiling corrosive liquids by that agent, and gives it consistence with flexible lead pipe, which he covers externally and internally. A better framework would be a spiral

connecting tube is made of sheet caoutchouc, about one-twelfth of an inch in thickness. A piece of the required length of the tube and twice the intended width is cut out and wrapped around a cylindrical glass rod *d*, Fig. 219, of diameter very nearly as great as that for the tube to be formed. The ends are then brought closely together by compression between the thumb and fingers as at *a*, and the excess removed, close to the surface of the rod, with a pair of clean sharp scissors. The freshly cut edges being further pinched together throughout the length of the tube, form a close, air-tight, scarcely perceptible joint. The rod is then to be withdrawn, and the tube thus formed carefully drawn over the end of one of the glass tubes to be connected, so as to form an extension for the reception of the end of the other. The two ends should approach each other almost to contact, a minute interval being necessary to afford the requisite flexibility. This junction-pipe is fastened to the surface of the tube by fine twine wrapped or tied around each of its ends, as shown at *x*, Fig. 218.

Fig. 219.



The gas-bottle thus fitted is connected, by means of a per-

coil of wire. The tubing made of canvas imbued with caoutchouc is less durable, and does not admit of such general application.

Before forming the tube above mentioned, it is better to warm the caoutchouc, by which its flexibitity is increased and its cut surface made to adhere more readily and closely. The scissors cut more freely when previously moistened. These flexible joints not only relieve the apparatus of stiffness and consequent liability to fracture, but enable the operator to adjust it more rapidly and satisfactorily than he could possibly do without them. A little practice upon shreds will give great proficiency in the art of forming india-rubber tubes and joints.

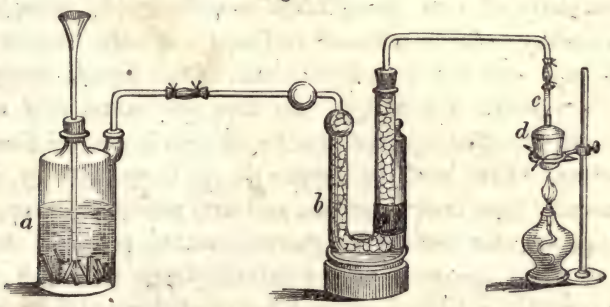
India-rubber for this purpose is now made by Goodyear, New York, who sells it in sheets of various sizes. Ready-made tubing of various bores is also furnished by the same manufacturer. Gas bags are likewise made of caoutchouc. The larger sizes, pp. 170, 172, are to be procured from the manufacturer. Smaller ones, for nice purposes, may be readily made from the rubber bottles of the shops. One of uniform thickness, and as free as possible from indentations and imperfections, is softened in boiling water or by exposure for several days to contact with ether, and then adjusted upon a stop-cock with a syringe attached. The air must next be injected slowly, so that the expansion of the bag may be gradual and uniform throughout all its parts; or the bag may very conveniently be blown out with the mouth.

forated cork with the drying-tube *d*, filled with lumps of dried chloride of calcium. At the opposite end of the drying-tube *e*, is another tube with a bulb blown in its centre, for the reception of the substance to be reduced, and in which it is heated by the flame of a spirit-lamp. This tube, like the other, is annexed by elastic joints to the short tube connected with the desiccating-tube through a perforated cork.

This plan, first proposed by Berzelius, was used by him in the synthesis of water, binoxide of copper being the substance employed to abstract the hydrogen, its oxygen forming water therewith.

A modification of the foregoing apparatus is shown by Fig. 220,

Fig. 220.



which exhibits a closed crucible of platinum, as the receiver, in place of a glass bulb, it being necessary, in certain instances, to exclude the direct contact of air during and immediately after the heating.

Hydrogen is a powerful reducing agent, and leaves the metal absolutely pure. At a red or white heat, its action will reduce the oxides of lead, bismuth, copper, antimony, zinc, iron, cobalt, nickel, tungsten, molybdenum, and uranium.

The heat should not be applied to the bulb until it is entirely freed from air, which may be done by allowing the hydrogen to pass over some minutes previously. A disregard of this precaution may cause an explosion from the combustion of a mixture of hydrogen and atmospheric air.

The above apparatus answers very well for decomposing metallic sulphurets by chlorine. It is also applicable for heating solids in gases, and serves for the preparation of chloride of sul-

phur, of phosphorus, and of many other volatile chlorides. For this purpose it is only necessary to replace the flask *A* by other suitable generating vessels, and the extreme end of the exit tube by a tubulated retort with its beak bent downwards and leading into the recipient, kept cool by a frigorific mixture.

The tubes for these purposes must be of hard glass and entirely free from lead, and not exceeding a third of an inch in width. The bulbs should be of 1½ inch diameter. The chlorcalcium tube may be three-fourths of an inch wide.

There are other modes of reduction, of less general application, however, than the preceding. Metals may be precipitated in a free state, in some instances, from solutions, by presenting bodies for which their oxygen has a stronger affinity; thus, for example, protosulphate of iron precipitates metallic gold; phosphorous acid, mercury; and formic acid or formate of soda, both of these metals, and also silver and platinum, if the liquids containing them in solution are boiled. So also one metal may reduce another if the affinity of the first for oxygen is greater than that of the last. Thus metallic copper throws down mercury, silver, and arsenic, from their solutions, and iron precipitates copper.

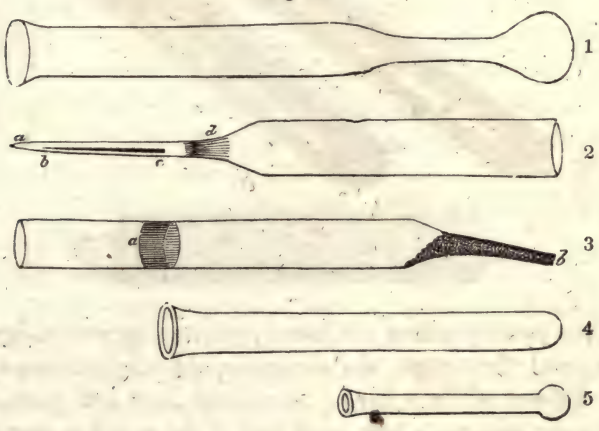
Metals are also reduced by galvanic action, practical illustrations of which are seen in the galvanoplastic art. All oxides which resist the combined action of heat and charcoal or hydrogen, are reduced by the agency of galvanism.

Reduction by Carbonic Oxide.—Another convenient agent of reduction, employed in the same manner as hydrogen, is carbonic oxide, made on a small scale by the action of oil of vitriol on oxalic acid, and separation of the carbonic acid produced at the same time, by milk of lime. It readily reduces the metallic oxides of nickel, iron, zinc, that of lead at a very low temperature, and that of copper below a red heat. For heating in manufacturing processes, it is made by regulating the admission of air to a deep bed of ignited anthracite or other coals, and driving a blast of air horizontally through the gas as it issues from the fire, all other access of air being prevented. It has in this manner been applied to reheating and puddling furnaces. Carbonic oxide is doubtless the great reducing agent in large metallurgic operations.

Roasting and Reduction in Tubes.—In very delicate experi-

ments, and particularly when the volatile matter expelled by the heat is to be collected for examination, roasting and reduction are effected in small glass tubes closed at one end. The glass must be white, difficultly fusible, and free from lead. The substance is placed in the lower or closed end of the tube, which is then inclined and heated over the spirit-lamp, as shown in Fig. 229. In this way sulphur and arsenic may be sublimed from certain of their compounds, and mercury from less volatile metals. By leaving the tube open at both ends so as to allow free access of air, many volatile bodies are oxidized, and collect, on congelation, in the upper part of the vessel. Those tubes, with a bulb blown at their lower end, as shown at 1, 5, in Fig. 221, are most applicable for decrepitating substances.

Fig. 221.



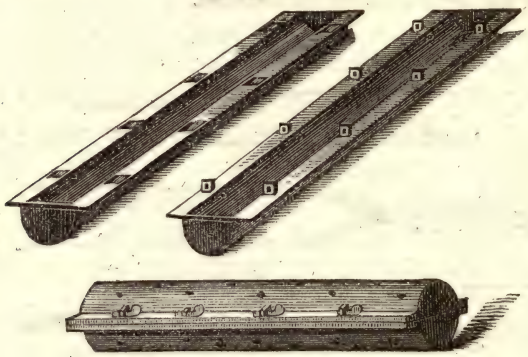
The above drawing exhibits the several forms of tubes used for the reduction of metals, and particularly the separation of arsenic and mercury from more fixed matter. Any of these forms, or even a small test-tube 4, will answer. Berzelius prefers the shape of 1; Rose that of 2; Liebig that of 3; and Clarke that of 5.

The letters *a b c* in 2, and *b* in 3, indicate the position of the substance to be roasted together with its reducing agent, and *d* and *a* in 2 and 3, the rings of condensed volatile matter sublimed by the heat. Berzelius and Rose's, and Liebig's tubes are three inches in length; Clarke's two inches. Their diameters vary

from one-sixteenth to one-fourth of an inch, according to the amount of substance to be heated.

Combustion in Glass Tubes.—The tube which contains the substance to be heated, should be made of hard and refractory glass entirely free from lead. Its position in the furnace is shown by Fig. 139, which has already been fully explained. When it is designed to apply a very intense heat to the tube, the latter should be enveloped in a jacket, to prevent its bursting or blowing out in places. This jacket is a strong iron plate mould, with a lining of plaster of Paris. It is shown in two half portions, as well as closed, by the annexed figure.

Fig. 222.



The two semi-cylinders are bound into one by iron wedge fastenings; and throughout the circumference it is perforated with holes. Plaster of Paris having been made into stiff paste, with a little water and cow's hair, each half of the mould is then filled with it; the combustion-tube next imbedded in one of them, and when the plaster begins to set, the other is placed on top, and the two fastened together. When the plaster has hardened, it is ready to be heated; but the heat must be gradual at the early part of the operation.

Porcelain and Metallic Tubes.—For the reduction of some oxides by contact with gases at furnace temperature, for the decomposition of certain organic matters, such as oils, &c., and for effecting many combinations of gases with solids, the glass tubes are replaced by those of porcelain, iron, or platinum.

Porcelain tubing should be selected with care. It should be

straight, perfectly cylindrical, free from defects, glazed internally, and as thin as possible. These tubes are adjusted in manner as directed for those of glass, and heated over the furnace, Fig. 126; but as they are not refractory, care must be taken in heating them. It is advisable to give them an exterior coating of fire lute, and then dry them. The fire should be ignited, and all moisture expelled from the charcoal before they are placed in the furnace, otherwise their fracture may result. It is indispensable, too, that the heat shall be carefully managed, and after the completion of the process, the tube must not be removed from the furnace until it has entirely but gradually cooled.

Iron tubes are used for the decomposition of water, potassa, and for other operations to which those of glass and porcelain are not adapted, by reason of inability to withstand high heat. Gas tubing is the most economical, and can be had of all lengths and diameters. These also should be covered exteriorly with luting so as to prevent the oxidation of the iron by the fire.

Metallic tubes of small size may be heated over the furnaces, Fig. 139, but those of larger dimensions require the use of the furnace, Fig. 126. The circular openings *x*, *x*, in each side, are especially for the passage of a tube. The grate should be elevated, so that the fire may entirely surround it.

Metallic tubes are adjusted to generating and other apparatus by means of metallic couplings, gallows screws, or, in some cases, by fire lute. This latter does not make a secure or tight joint, and is only used in the absence of more convenient means. The ends of the tube should project far enough beyond the sides of the furnace to allow their refrigeration when necessary. The gas may be introduced directly from the generating vessel, or from a caoutchouc bag or gasometer, merely by adjusting the end of the tube with the mouth or outlet by a suitable coupling. The resultant product may, in like manner, be collected by similar adaptations to the other end.

Fragments of flint or coils of iron or of platinum wire, placed within the tube, increase the points of contact of the contained matter and greatly promote its heating.

As short tubes are occasionally used for effecting the combination of substances alterable by exposure in a hot state, they

should, for such purposes, be fitted at the ends with screw plugs, to prevent access of air.

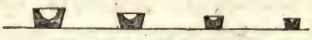
Platinum tubes are only used on rare occasions for particular purposes, to which those of glass, porcelain, or iron, are inapplicable.

CHAPTER XVI.

CUPELLATION.

GOLD and silver are *assayed* by the agency of heat and litharge in shallow, slightly conical crucibles, Fig. 223, called *cupels*.

Fig. 223.



This process separates these metals from any debasing admixture; for, when the alloy is heated together with litharge, all but the precious metals are oxidized; and the oxides thus formed, together with the semi-vitreous litharge, are absorbed by the cupel, whilst the nobler metal remains as a button of absolute purity.

Cupels.—These small crucibles are generally made of bone-ash, because that material fulfils better than any other the necessary requirements. It is resistant to the action of the fused oxides of lead and bismuth, and by its porosity facilitates the penetration of the oxides, and at the same time is, when made into shape, strong enough to bear handling without fracture. The cupels used at the United States Mint are made in a matrix of 1⅜ inches diameter. The semicircular cavity is two-fifths of an inch deep in the centre. This size, however, can be varied and they may be made smaller or larger according to the quantity of matter to be operated upon. Their mode of manufacture is as follows:—Take bones or bone-black and calcine them in an open crucible until the expulsion of all animal and carbonaceous matter, which is known by the residue assuming a whitish appearance. Empty the cooled contents of the crucible into clean water, and give it repeated washings in fresh waters to remove all soluble matter; filter and dry. The dried matter is pure

phosphate of lime with a minute portion of partially decomposed carbonate.

Make the powder, calcined and purified as directed above, into a paste with water or preferably with beer (Mitchell), in the proportion of 4 lbs. of bone ash to half a pound of beer. The above mixture is just sufficiently moist to adhere strongly when well pressed, but not so moist as to adhere to the finger or the mould employed to fashion the cupels. The mould, Fig. 224, of polished iron consists of two pieces, one a ring having a conical opening; the other, a pestle having a hemispherical end fitting the larger opening of the ring. In order to mould the cupels, proceed as follows: Fill the ring with the composition, then place the pestle upon it, and press down as much as possible. By this means, the moistened bone-ash will become hardened, and take the form of the pestle; and the latter must then be struck on the head with a heavy mallet, to insure greater consolidation of the cupel. It is then to be turned lightly round, so as to smooth the inner surface of the cupel, and withdrawn; after which the cupel must be removed from the mould by a gentle pressure on the narrowest end. When in this state, the cupel must be dried gently by a stove; and lastly, heated in a muffle, to expel all moisture. It is then ready for use.

Fig. 224.

There are two or three points to be observed in manufacturing the best cupels. Firstly, the powdered bone-ash must be of a certain degree of fineness; secondly, the paste must be neither too soft nor too dry; and thirdly, the pressure must be made with a certain degree of force. A coarse powder, only slightly moistened and compressed, furnishes cupels which are very porous, and break on the least pressure, and which allow small globules of metal to enter into their pores,—the most serious inconvenience of all.

When, on the contrary, the powder is very fine, the paste very moist and compressed very strongly, the cupels have much solidity, and are not very porous, the fine metal cannot penetrate them, and the operation proceeds very slowly; besides, the assay is likely to become dulled and incapable of proceeding without a much higher degree of temperature being employed.—(*Berthier.*)

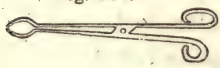
The Process of Cupellation.—In order to protect the cupel from contact with the fire, and at the same time allow a free access of the air, it is when being heated placed in a *muffle.* The muffle is a refractory vessel of baked fire clay, Fig. 225, arched above, flat-bottomed, and pierced near its base with small lateral openings for the passage of the heat. Excepting these apertures, and that at the front for the introduction of the cupels and inspection of the process, the muffle is entirely closed. Its dimensions depend upon the size of the cupel and of the furnace in which it is to be heated.

Fig. 225.

Its position in the furnace (*D*, Fig. 137), must be exactly level, and to protect it from the corrosive effects of volatilized oxides, it may be payed over with a thin paste of bone-ashes. The muffle being properly arranged in the furnace, and held firmly in its place by lute, the cupels are then introduced, and the fuel (charcoal) ignited. The lead must be perfectly pure. It can be reduced, for this purpose, from refined litharge. "When the cupels have been exposed for half an hour, and have become white by heat, the lead is put into them by means of the tongs, Fig. 226, and as soon as this becomes thoroughly red and circulating, as it is called, the metal to be assayed, wrapped in a small piece of paper, is added, and the fire kept up strongly until the metal enters the lead and circulates well, when the heat may be slightly diminished, and so regulated that the assay shall appear convex and ardent, while the cupel is less red,—that the undulations shall circulate in all directions, and that the middle of the metal shall appear smooth, surrounded with a small circle of litharge, which is being continually absorbed by the cupel. This treatment must be continued until the metal becomes bright and shining, or is said to '*lighten;*' after which, certain prismatic colors, or rainbow hues, suddenly flash across the globules, and undulate and cross each other, and the latter metal soon appears very brilliant and clear, and at length becomes fixed and solid. This is called

Fig. 226.

Fig. 227.



the '*brightening*,' and shows that the separation is ended. In conducting this process, all the materials used must be accurately weighed, especially the weight of the alloy before cupellation, and the resulting button of pure metal. The difference gives the quantity of alloy."

When the operation is completed, the cupel is to be withdrawn from the fire, and allowed to cool, and the metallic button then removed with the pincers. If the assay is a good one, it will detach easily. The button should be round and brilliant upon its upper surface, but rough and striated at the bottom. If its surface is dull and flat, too much heat has been employed; on the contrary, when it is spongy, adheres tenaciously to the cupel, and contains scales of litharge, there has been a deficiency of heat, and the fire must be again urged, and the flowing of the metal promoted, by adding to the cupel a little powdered charcoal. Complete fusion is indispensable to the success of the operation. If too much lead has been added, the cupel is allowed to cool, the button carefully separated, so as to be free from adherent particles of ash, and transferred to a fresh cupel and the process continued. In experienced hands, the pneumatic blast, p. 169, may be made to replace the furnace in the process of cupellation.

Cupellation in Taylor's Muffle.—Mr. T. Taylor (*Memoirs of Chem. Soc.* vol. iii. p. 316), claims for his new form of muffle the following advantages:—"1st. Crucibles may be maintained at a much higher temperature than can be readily obtained when the ordinary muffle is used, while the degree of heat and the quantity of air admitted may be regulated with the greatest nicety. 2d. Owing to the greater draught of air, the oxidation of the lead (in the process of cupellation) is more quickly effected; and lastly, by looking through an opening in the furnace cover, the operation may be watched from first to last.

"Two black lead crucibles of the same size are ground flat, so that when applied one to the other they may stand steady. An oblong or semicircular notch is cut out of the mouth of one of the crucibles, and a hole is also drilled through its bottom. This crucible, when placed on the top of the other, constitutes the muffle, and of course resembles in shape a skittle. To cupel with this apparatus, the lower crucible is nearly filled with clean

sand, set upon the bars of the grate in the centre of the furnace, and brought to a low red heat. The cupel containing the lead of the alloy is then placed upon the sand and immediately covered by the crucible, taking care that the notch in its side shall be opposite to, and correspond with, the furnace door; more fuel is added, during which it is well to cover the hole in the top of the muffle with a crucible lid, in order to prevent the admission of dirt. When the muffle has become throughout of a bright red heat, the furnace door is thrown open, and the ignited fuel gently moved aside so as to permit a view of the side-opening in the muffle. The current of air which is thus established through the muffle instantly causes rapid oxidation of the lead, and this may be regulated at pleasure by closing the door more or less. If from the fuel falling down, any difficulty should be experienced in maintaining a free passage for the air, a portion of a porcelain tube, or a gun-barrel, may be passed through the furnace door to within an inch of the muffle; but this proceeding is generally rendered quite unnecessary, by taking care to place some large pieces of coke immediately round the door of the furnace."

CHAPTER XVII.

SUBLIMATION—DISTILLATION.

When simple or compound bodies which are either wholly or in part capable of assuming the aëriform state are subjected to heat, they or their most volatile constituents, upon reaching the required temperature, rise in the form of vapor. If these vapors, in their transit, are intercepted by a surface of a lower temperature, they condense and take a solid or liquid form, according to their nature. If the product is a solid, it is termed *sublimate*, and the process by which it is obtained is SUBLIMATION;—if it is liquid or gas, it takes the name of *distillate*, and the operation which yields it that of DISTILLATION.

Both of these processes are indispensably useful in chemistry, for they afford the facility of taking advantage of the unequal volatility of bodies for their separation.

As instances of sublimation, we have calomel and corrosive sublimate made by heating equivalent proportions of sulphate of mercury and common salt; benzoic acid evolved from the gum; pure indigo from the commercial article, and camphor from the crude material. Iodine is sublimed to free it from impurities; biniodide of mercury to convert it into crystals; naphthalin to free it from empyreumatic matter, and succinic acid to separate water.

In like manner, multitudes of instances of the importance of distillation, in the everyday-processes of the chemist and the manufacturer, might be adduced. It is employed in the separation and rectification of alcohol, the preparation of the ethers, of many mineral and vegetable acids, and of a very great number of other chemical products.

SUBLIMATION.

The implements of sublimation are manifold, and vary in size and construction with the quantity of the substance to be heated, the nature, degree of volatility, and the affinity of the subliming body for the oxygen of the atmosphere.

There are certain rules to be observed in order to a successful execution of the process; but whatever the apparatus, its arrangement and management must be such that there shall be no diminution of the temperature of the vaporized matter until it reaches the recipient in which it is to be refrigerated and condensed.

The covers of flat subliming vessels and the recipients or condensing portions of those of other shapes, must invariably be out of and above the fire, and exposed to the cooling influence of air. When the sublimed particles are very volatile, it will even be necessary to promote their condensation by covering the recipient with rags, which are to be kept constantly wet with cold water or some other refrigerant.

The usual mode of heating subliming vessels is by the sand-bath, but for some substances requiring a very high temperature for their volatilization, direct fire is necessary. For small experiments, the lamp will be most convenient; but in large operations, the furnace must be used.

In order to prevent explosion, the small opening in the top,

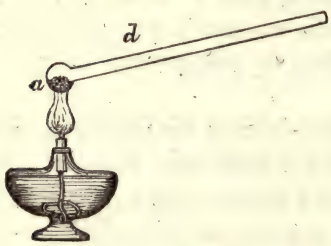
at the centre of the refrigerant, must be only closed with a plug of raw cotton, and should be freed from obstruction by occasional poking with a wire. When the escape of vapor through this hole is rapid, the heat is too high and must be diminished immediately.

After the completion of the operation, the apparatus must be left to cool before it is opened or the recipient removed.

The necessary breaking of close vessels for the removal of the contents, renders their use expensive; whenever, therefore, the nature of the substance will permit, an alembic with detached head should be preferred. Such vessels are more economical and easy of management, but generally require that their joints be made impermeable by luting.

Sublimation in Tubes. — Sublimation is very available in analyses for detecting the presence of minute quantities of volatile metals, acids, and other substances, the implement for the purpose being a small tube of such form as is shown in Figs. 221, 228. After the introduction of the substance, previously powdered and dried, the tube is drawn out at its open end to a fine orifice, and the lower part heated gradually over the flame of a spirit lamp (Fig. 228). The volatilized portion will be condensed upon the sides of the upper and cooler parts. By dividing the tube with a file, the sublimate can be exposed for microscopic examination or removed for further assays under the blow-pipe. The tubes for sublimation may be from 4 to 8 inches in length, and from an eighth to half an inch in diameter, according to the quantity of the matter to be sublimed, and the required delicacy of the operation.

Fig. 228.



Berzelius uses a tube entirely open at the upper end for those sublimations in which there are two volatile products, of which one is to be drawn off entirely in the form of gas by the absorption of oxygen from the atmosphere, and recognized by its odor, and the other condensed in the upper part of the tube; as, for example, a mixture of sulphur and selenium.

Faraday gives the form of a tube apparatus (Fig. 229) for condensing heavy vapors or easily fusible substances, as naphthaline, iodine, &c. The bent tube *b* is of a diameter only large enough to allow its free passage over the subliming tube *a*. The upper part of the middle portion of the tube may be kept cool by paper or cloth wrappers moistened with water, in order to promote the condensation of the sublimed matter. The heat of the spirit-lamp is sufficient for these small operations, and the apparatus, as adjusted, may be properly maintained by the upright clamp, Fig. 186.

Fig. 229.

Sublimation in Flasks.—Florence or sweet oil flasks are well adapted to purposes of sublimation on account of their cheapness, uniformity of thickness, and power of resisting high heats. Having received their charge they are to be imbedded in a sand-bath to a depth above the level of the contents, and heat is to be applied gradually until the proper temperature is arrived at. The position of the flask should be inclined, so that its neck may lead directly into the recipient, as shown at Fig. 230. In this manner, considerable quantities of matter may be operated upon even at high temperatures, the glass bearing a red heat without injury. Another mode of arranging a flask for this process is to connect its neck, in the manner of a hood, with a long bent tube

Fig. 230.

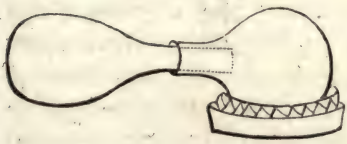
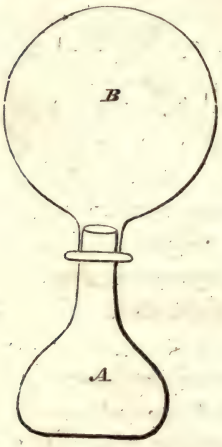


Fig. 231.

leading into the refrigerant and recipient, as shown in Fig. 231. The inconvenience of this arrangement is the condensation of the gaseous matter in the tube, the obstruction from which may, without great care, cause the explosion of the flask.

Flat-bottomed flasks of thin German glass are sometimes used,

Fig. 232.



but they are more expensive than oil flasks. Their position in the sand-bath is upright, and the flange around their necks acts as a support for an inverted globular flask which serves as a recipient. This arrangement, shown in Fig. 232, is admirable for the sublimation of substances, the volatile products of which are so aggregated as to form what are called *flowers*.

Sublimation in Retorts.—Glass retorts are more expensive and less convenient than flasks, except for the sublimation of very volatile matters. They are arranged as shown by Fig. 238, the beak, like the neck of the flask, leading into a wide-mouthed receiver. The alembic, Fig. 233, is frequently substituted for retorts, and is more convenient, as its head being detached from the body allows the more easy removal of the sublimed product.

Fig. 233.

Fig. 234.

Earthenware retorts with loose heads, Fig. 234, to be fastened by pins and lute, are employed for sublimations requiring high temperatures.

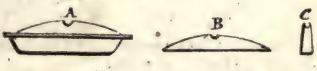
Sublimation in Crucibles.—The crucible for this purpose may be of clay, platinum, or iron, according to the nature of the substance to be heated. It is first coated with a layer of refractory

clay paste, and when this is dry, placed over a furnace fire. An inverted crucible of the same size with a small hole in its top, is then placed over as a recipient of the vaporized particles. The top crucible must be above and out of the fire. When the operation is finished, and the apparatus has cooled, the top may be removed and the crucible emptied of its contents.

Sublimation in Shallow Vessels.—In the treatment of substances which sublime at a low heat, a plate or capsule resting upon hot sand and surmounted by a glass funnel or a cone of glazed paper, as a condenser and recipient, answers every purpose, particularly in the sublimation of organic substances. The top of the funnel and cone should be drawn out to a small opening, and when the operation is finished the contents of the refrigerant may be removed by a feather.

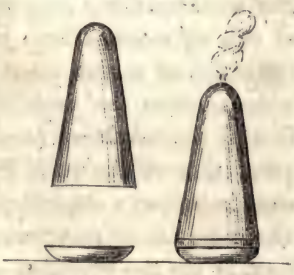
When iron capsules are used, as is often necessary in sublimations requiring high heat, they should be lined with a thick dough of fire clay. Capsules with flat bottoms and of thick sheet iron are most appropriate. Their dimensions may be six inches in diameter, and ½ to 1 inch in depth. The top B must be of earthenware and detached. The arrangement is shown in Fig. 235. This implement requires a furnace heat. The cover should be tightly cemented with fire lute, and when the whole has cooled, the cover may be taken off and the adherent mass of sublimate removed with a spatula. The small cone *c* is to be kept over the hole in the cover to arrest any escaping vapors. When it is necessary to probe the cavity, it may be temporarily removed with the tongs. A diaphragm of porous white paper will arrest the passage of any empyreumatic matter, and pass the sublimate free from color.

Fig. 235.



Two very concave watch-glasses, placed the one upon the other with their convex surfaces outward, make a very neat subliming apparatus for minute quantities of rare matter.

Fig. 236.



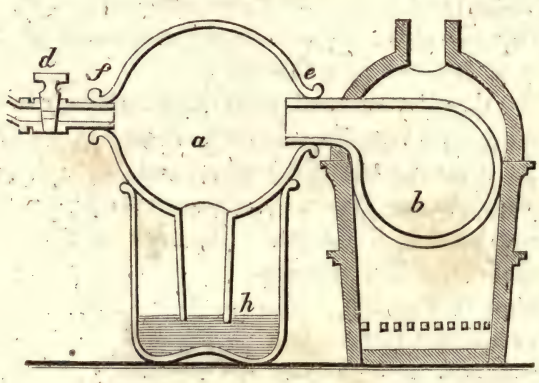
Flat vessels, with tall conical caps, Fig. 236, are also made of biscuit and earthenware for subliming operations.

Ure's Apparatus.—This is a very convenient arrangement, Fig. 237, consisting of two metallic, glass, or porcelain vessels. The lower one is the recipient of the matter to be sublimed, and the upper *a*, which is the larger, covers the former, and is to be filled with cold water, to be replaced as fast as it evaporates. When the process is completed, the sublimed matter can be removed from the exterior of the cover.

Fig. 237.

Henry's Apparatus for Hydro-Sublimation.—This arrangement, shown in Fig. 238, has been proved by experience to be

Fig. 238.

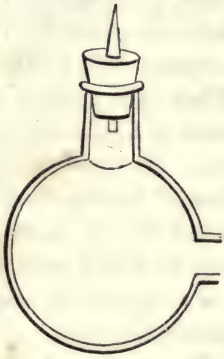


practically useful. It is employed in manufacturing laboratories for the sublimation of calomel, but is equally applicable for other substances; and, by lessening the dimensions of the several pieces, may be made very convenient for experimental purposes.

It consists of a large globular glass vessel *a*, with a long straight neck, and two short, lateral tubulures of equal width. For manufacturing purposes the globe must be of stoneware, and of two or more gallons capacity. In either case it rests upon the ledge of a blue stone-ware cylinder *h*, containing sufficient water to close the neck of the globe, which dips lightly into it. One of the tubulures receives the neck of the retort *b*, and the other that of the still, Fig. 25, which furnishes the steam, or, what is better, a conduit pipe from the generator, Fig. 13 or 14. The retort *b*, of earthenware, or iron, coated interiorly with fire clay, is for the evolution of the calomel or sublimate in vapors. It is wholly enclosed in the furnace, and its very short neck passes

immediately from it into the globe *a*, so as to prevent the condensation of the sublimate in the neck and upper portion. The joints should be tightly luted. The success of the operation depends mainly upon a proper management of the fire and supply of aqueous vapor. The heat should be just sufficient to drive over the sublimate slowly, and the steam should be supplied in large excess, and simultaneously with the appearance of the vaporized solid. For this purpose the steam-conduit must be fitted with a cock for the regulation of the flow of its contents of vapor. As soon as the sublimed molecules come in contact with the aqueous vapor, they are condensed in the globe *a*, and precipitate as powder (p. 100) into *h*.

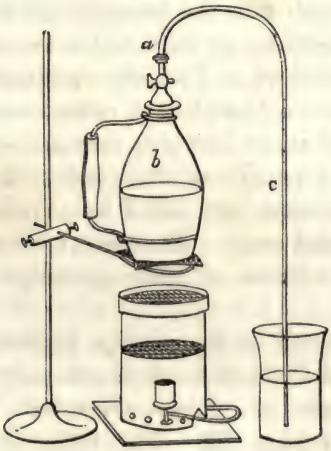
Fig. 239.



By increasing the size of the globe *a*, threefold, diminishing the orifice of its neck by means of a small glass tube passing through a perforated cork, and by omitting the tubulure on the other side, the steam may be dispensed with for the sublimations of volatile solids into flowers. The neck in this case must point upwards.

For experimental operations, a small earthenware retort and

Fig. 240.



glass globe will answer every purpose. The steam can be sup-

plied from the copper washing bottle, Fig. 240, by substituting for the spirting tube *d*, a flexible leaden pipe *c*, which is to be connected with the neck of the flask by a coupling-screw *a*. The gas or spirit lamp will furnish ample heat for the generation of steam in this apparatus.

DISTILLATION.

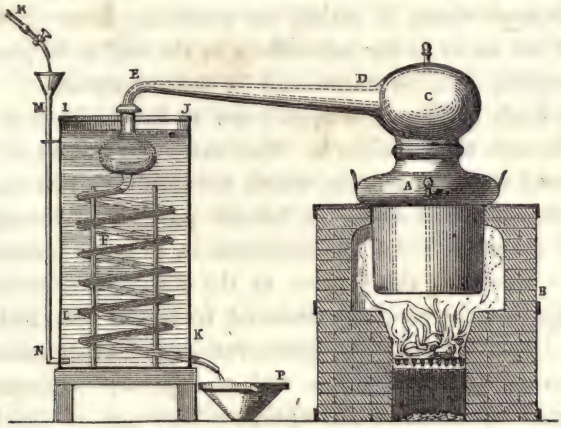
A process by which substances are heated for the separation of a volatile from a more fixed portion. The apparatus for the purpose consists of a close vessel in which the heating takes place, a refrigerant for the condensation of volatilized particles, and a recipient for the retention of the product; the two latter purposes being often, however, fulfilled by the same vessel. When this product condenses as a fluid, the process takes the name of *liquid distillation*, and if as a gas, of *gaseous distillation*. The subjection of a body to very high heat, for the purpose of decomposing it and receiving the generated products, is called *dry* or *destructive distillation*. In SUBLIMATION, which may be styled *solid distillation*, the volatilized matter is received and condensed in one vessel without the necessity of an intermediate refrigerant.

The process of distillation is one of the most indispensable in chemical investigation, as by its aid we can not only separate liquids of different volatility, but also collect new volatile products which may result from the decomposition of single or mixed substances. As instances of its valuable use, we can by its aid separate the essential oil and volatile constituents of plants and of other materials,—recover alcohol, ether, or any valuable volatile liquid, from solutions in which they are solvents,—refine a liquid from its fixed impurities,—free it from fixed matter which it may have in solution, and, aided by an absorbent material, remove any contained water. Moreover, it allows the collection, either free or in solution, of gases generated by chemical reaction.

The Still.—The still is the common implement used in large operations of liquid distillation. It is generally made of copper, and is tinned internally. A convenient form has already been fully described at page 52. The following figure exhibits another of handsomer appearance, but constructed upon similar

principles. It is mounted in brickwork, but can as readily and with as good results, have its position in the more economical iron cylinder, Fig. 24.

Fig. 241.



By way of illustrating the necessary manipulations, we will describe the different steps of the operation as commonly performed.

The substance to be distilled is placed in the body A, the pewter or tinned copper head C, is luted on and adjusted to the pewter worm E, and the fire is lighted in the furnace. To insure facility of management, the several parts of the arrangement should be made to fit accurately to each other. As the heat increases, the contents of the body or cucurbit begin to boil, and that portion volatilizable at the temperature of the applied heat mounts in vapor to the head or *capital* C, there partially condenses, runs into the beak or neck D, and ultimately into the spiral worm E B, where, together with any uncondensed vapor, it is liquefied and cooled by the surrounding water previous to its exit into the recipient P, which may be an open pan if the product is not volatile, and a glass bottle or carboy if it is. The cooler I J K L, in which the worm is immersed, consists of a wooden cistern filled with water, which requires to be constantly cool, and therefore must be frequently renewed. For this purpose, there is a conduit N M attached, which receives cold water from the hydrant pipe R, and conveys it in a constant stream to the bottom of the cistern, so that it may displace the heated water,

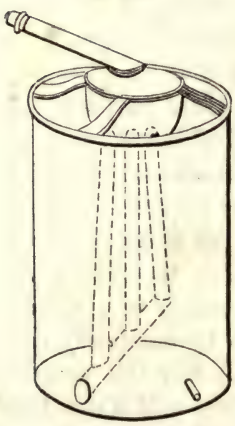
which has become lighter by expansion, through the lateral outlet at the top. This water, already heated, can be more economically used for making distilled water than when cold, as it takes less fire to boil it when transferred to the still. If the cistern is kept clean, it makes an excellent reservoir for the supply of hot water to the laboratory, as the still is frequently in use for making distilled water, and for other purposes.

When fresh additions of liquid are to be made they can be poured through the tubulure A. This saves the trouble of taking off the head of the apparatus, which need only be removed after the completion of the operation for the purpose of cleaning the still and its parts. As the residuum is, in many instances, as much the object of the process as the *distillate*, it must, when such is the case, be carefully removed from the still, and transferred to a suitable vessel for preservation or further reaction.

The size of the still varies with the amount of material to be operated upon. For the ordinary purposes of the laboratory it need not exceed fifteen gallons capacity. It must be proportioned so as to have as much heating surface as possible, while, at the same time, its height is sufficient for the foaming and frothing of its contents without danger of their boiling over into the neck.

We have described a spiral worm, because that is the usual form of refrigerants, an important point in the construction of which is to provide as much cooling surface, and consequently as great a length of pipe as possible in a small space. Schrader's condenser, Fig. 242, which is preferred by some manufacturers, because more easily cleaned, consists of a metallic ball, the upper part of which projects above the water contained in the cooler. From the lower side of this ball three straight tubes proceed, and conduct the vaporized particles downwards into the exit tube with which they connect. The exit tube is closed at its upper end with a cock, and open at the other for the escape of the condensed liquid. Gedda's

Fig. 242.



condenser, already given at p. 48, is still more convenient than either of the two preceding.

Whatever the form of the refrigerant, its mode of action is the same. It is constructed so as to facilitate as much as possible the perfect and rapid condensation of the enclosed vapors. The greater the amount of surface which it presents to the water, the more effectual its action; for the sooner the heat, absorbed by the distillate in assuming the gaseous form, is abstracted by the surrounding water, the more rapidly it becomes condensed and cooled. The condensation may be hastened by surrounding the recipients with a frigorific mixture, which, if the vessel be of glass, must be at first applied gradually, lest its too sudden cooling causes its fracture.

Volatile liquids are distilled by the heat of BATHS; and for those liquids which corrode metals, a stoneware still must be used.

Distillation in Retorts.—Retorts are egg-shaped vessels, answering a more convenient purpose than the still in the nicer distillatory operations. They are mostly of glass, but for some processes those of porcelain, earthen and stoneware, platinum and iron, are necessary. Retorts are also used in technical operations, and the laboratory should be supplied with a series ranging from those of a half ounce up to several gallons capacity. Glass retorts should be made of hard, white glass, free from lead. Those of German crown-glass are very thin, but of uniform thickness and of sufficient strength, and moreover withstand both high temperatures and the corrosive action of acids and alkalies. The surface must be perfectly smooth and free from blur or striæ.

Some judgment is required in the selection of retorts. One properly constructed is exhibited in Fig. 243. It is seen that the neck proceeds laterally from the summit of the body, forming a wide tube at its origin, which tapers gradually into a narrow beak. The arch of the retort should be so fashioned as to reverberate any particles of boiling matter that may spirt upwards against it, and thus prevent their overflow into the beak. A large neck facilitates the process, because it allows more room for the accumulation of vaporized matter, and presents a proportionally less surface to the cooling influence of the atmosphere.

It is very essential that the curve between the neck and the body *a*, Fig. 243, should be so formed as to make the *straight* line *a b* form an obtuse angle, with the dotted line *b a*. If, on the contrary, it is made as shown by Fig. 244, which presents the

Fig. 243.

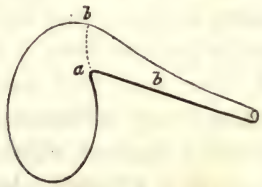


Fig. 244.

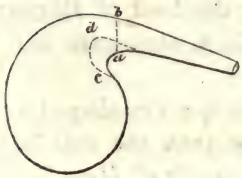
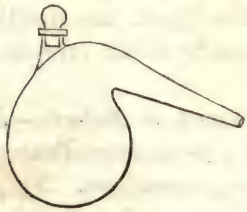


Fig. 245.



usual form of those sold in the shops, the vapors, condensing in the arch as far as the dotted line *a b*, fall back again into the body, whilst, in Fig. 243, the dividing line, from which the distillate commences to flow, is much nearer to the body. So that a retort like Fig. 243, will distil twice as rapidly as another similar to Fig. 244, which, however, when it has the form shown by the dotted lines *c d a*, becomes equally convenient.

The pear-shaped retort, Fig. 243, being deeper in the body or bulb, is better fitted for distilling volatile substances, and others which foam and swell upon being heated. The globular form, Fig. 245, presents less depth, but more heating surface, and is, therefore, better adapted to those liquids which boil quietly and distil more slowly.

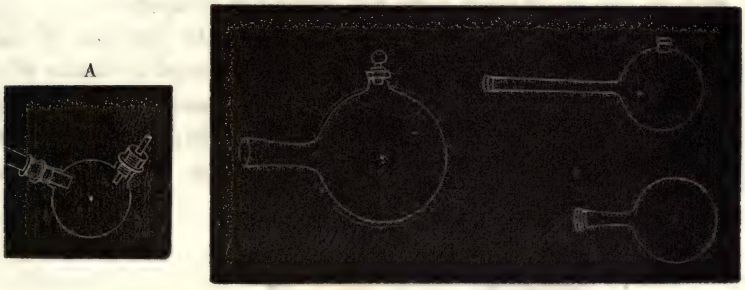
A great improvement to the plain retort, is the addition of a glass stoppered tubulure to the neck, as at Fig. 245. The tubulure should have its position exactly as shown in the cut, so that the vapors condensing about it may flow back. Tubulated retorts are preferable, because they are more readily cleansed and charged than those of plain shape; moreover, they admit of fresh

additions to their contents without the necessity of disturbing the arrangement.

The vessels into which the distillate from the retorts passes are technically termed *receivers*, Fig. 246. They should be of glass, except in a few special cases, and always free from lead; care being observed, at the same time, to select those which, while thick enough for strength, will be sufficiently thin to bear sudden changes of temperature. The usual shape is that of a globe with

Fig. 246.

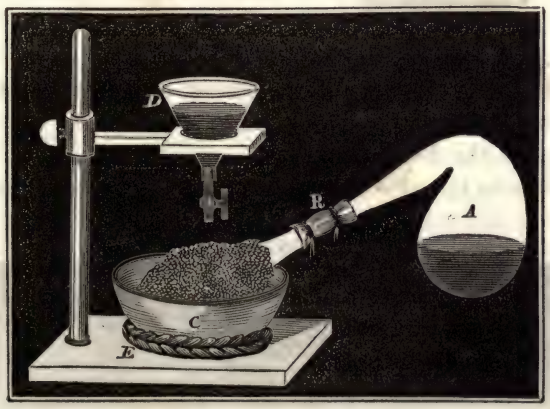
A



a neck, widening gradually towards the mouth, for the reception of the tapering ends of the retorts.

To render them available for connection with other apparatus besides the retort, as shown by A, Fig. 246, they are often fitted

Fig. 247.



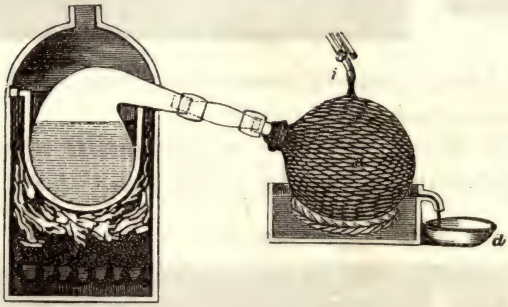
with tubulures. In rare cases, the long neck tube is replaced by a tubulure. The interior of the tubulures should be perfectly

round and smooth, so that corks may be tightly fitted in them according to necessity.

If the distillation is to be urged over an Argand lamp, the neck of the receiver to be attached to the retort should be long, and the connection made by inserting the beak of the latter in its mouth, Fig. 247, and by rendering the joint air-tight with a wrapper of india-rubber cloth, as shown at R in the figure. The funnel D is charged with water, which flows in a thin stream, regulated by the cock in the barrel, upon the receiver, covered with sponge or bibulous rags, and resting in a capsule C.

If the retort is to be heated in a furnace, the junction of the beak with the tubulure of the receiver is tightened by means of a perforated cork through which the beak passes, and sealed, if necessary, by a coating of flaxseed and whiting lute, as shown at R, Fig. 248. The receiver B, resting upon a straw ring in

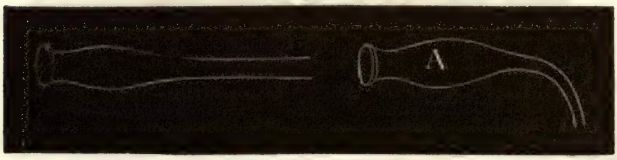
Fig. 248.



a wooden pail, is cooled by a stream of water from the hydrant pipe *i*, which, as it becomes warm, flows off into the funnel *d* leading into the drain.

In order to increase the surface of the beak, and consequently

Fig. 249.



to facilitate the liquefaction of the vapors passing through it into the receiver, there is often placed between the beak of the retort

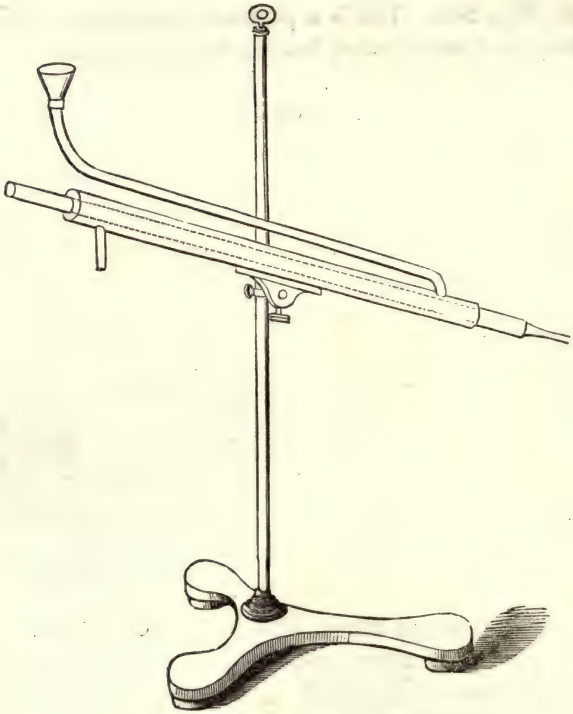
and the tubulure of the receivers, but connected with both, an adapter, Fig. 249. This is a pointed conical tube of white glass, free from lead, which, when leading from a condenser to a bottle,

Fig. 250.

takes a bent form, as shown at A in the same figure. Fig. 251 exhibits a complete arrangement of a distillatory apparatus, combining a tubulated retort with an S tube, an adapter, a recipient placed in a vessel with a constant stream of cold water flowing into it, and a syphon-tube with a second receiver. The curved adapter is needed where the receiver rests vertically instead of horizontally.

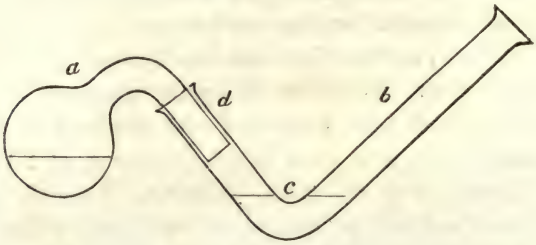
As it is requisite frequently, in distilling volatile liquids, to have a larger extent of cooling surface than is presented by the globular receiver, another form has been devised by Liebig, which is very convenient. It consists of a glass tube *a*, 25 to 30 inches long and two inch bore, connected with the beak of the retort, and running through a sheet brass cylinder *b*, of 20 inches in length and two or more inches diameter. The metal tube is closed at each end with perforated corks, through which the glass rod passes, and is held in a central position. A constant stream of cold water, supplied through the funnel-tube *c*, passes into the cylinder, surrounds the glass tube, condenses the vapor therein contained, and, becoming warm, passes out through the exit pipe *d*, to give place to cooler water. The figure below exhibits one

Fig. 251.



mounted upon an iron stand, with joint and sliding rod; from which, for small operations, it may be detached and supported by a wooden clamp.

Fig. 252.

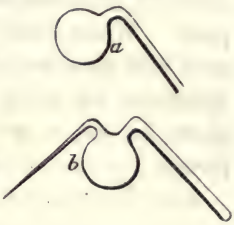


For micro-chemical distillations, the necessary apparatus may be formed of glass tubes blown into proper shape over the blowpipe table. Fig. 252 exhibits Clarke's tube retort and receiver; *a* the retort, of an ounce capacity; *b* the receiver, 8 by three

quarter inches, and *c* the distilled liquor. The junction of the retort and receiver (*d*) should be hermetical.

Plain bulbs *a*, and tubulated *b*, Fig. 253, are other forms:—the tube *b* of the latter serves for the suction of the liquor to be heated, and may afterwards be sealed in the flame of a spirit-lamp.

Fig. 253.



The means of heating these small vessels, are the small spirit-lamps, Figs. 151, 152, except when it is required to modify the heat by the intervention of a sand-bath, which requires a larger lamp. The clamp supports, p. 186, heretofore described, are of very great convenience in the adjustment of these tube arrangements.

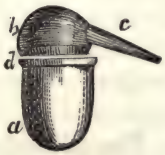
A simpler form of tube retort is shown in Fig. 254. It is

Fig. 254.

readily made by closing a tube at one end and bending it in a zigzag direction, as represented in the drawing. The liquid to be distilled is at *a*, and the recipient at *b*. To render it applicable to the generation and collection of gases, the tube may be drawn out at its open end and bent downwards, if necessary, to reach the receiver.

Platinum Retorts.—The size of these vessels varies from a quart down to an ounce, these capacities being adapted to all the purposes of an analytic and pharmaceutic laboratory. The usual form is shown in Fig. 255. The body *a* is nothing more than a stout crucible with a thick rim *d*. The head *b*, with the helm *c*, should be hammered from one piece, or else very closely welded together, and it should be ground at its rim so as to fit perfectly to the mouth of the still.

Fig. 255.



Platinum stills are very useful for destructive distillation, for determining the amount of matter, if any, lost by substances at

a red heat, for the distillation of matters not readily volatilized, of those which corrode glass, &c., and consequently as a substitute for lead in the preparation of fluohydric acid.

Those of a large size should be fitted with handles, so as to diminish their liability to defacement by transfer from place to place. When heated over charcoal, they should be well payed over with an external coating of fire-clay paste. Otherwise, the directions for using the platinum still are the same as those given for the crucible at p. 283. The gas or spirit lamp will furnish the amount of heat required for most operations.

Iron Retorts.—All iron retorts may be of cast metal. A very neat form for small operations is shown by Fig. 256. A simpler and more economical apparatus is a mercury flask, with an iron gas tube or gun barrel screwed into the top, and reaching nearly to the bottom, and another tube bent downwards. This arrangement, well fitted for distilling dry substances which require a high heat, may be modified by removing the centre pipe and inserting a screw-plug, and thus be made well adapted to the distillation of mercury. For distilling naphtha, caoutchicine, and similar substances, the usual form of a glass retort is sometimes preferred.

Fig. 256.

Fig. 257.

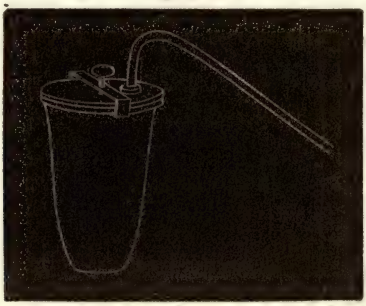


Fig. 257 exhibits an iron crucible retort, with a cover, which is held close to the body by means of a clamp, when the retort is in operation. A bent gas-tube carries off the distillate into a receiver.

Plate iron retorts, sometimes used for the generation of gases

by high heat, are referred to in the distillation of volatile substances.

All of these iron retorts are heated in furnaces. When not in use, they should be greased to prevent oxidation, and should be kept stoppered. One per cent. of platinum, it is said, renders iron resistant to acid and corrosive liquids.

Porcelain Retorts.—These implements, of shape similar to those of glass, are only used for dry distillations; but being fragile, require to be very carefully heated. Being opaque, they have not the advantage of glass, which allows the inspection of the contents of the vessel.

Earthenware and Stone Retorts.—The application of this ware to the purposes of distillation is very limited. To render it impermeable by gases, the retorts should be wet with a solution of borax, or else payed over with a coating of paste made from 9 parts of clay and 1 part of powdered borax, and then heated to fusion and gradually cooled. The usual form is that of the glass retorts.

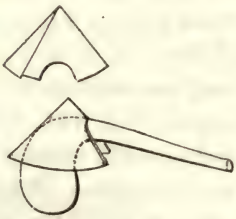
General Rules for Distillation.—In the distillation of substances which require a high heat, the vessel may be placed over the naked fire. If it is a metallic still, the cylinder, Fig. 24, affords every convenience for heating by this method. The universal furnace, Fig. 134, is the proper heating implement for earthen and metallic retorts; and the spirit or gas lamp for those of glass and porcelain. When the nature of the process requires a modification of the heat, it can be accomplished by means of intermediate BATHS, which will furnish any temperature required up to the boiling-point of the medium employed.

Glass and porcelain retorts should, if possible, never be heated over the naked fire, because of their great liability to fracture. The impossibility of maintaining a uniform heat is a serious objection to this mode, for the ebullition, though rapid, is not uniform. When it is necessary to use the naked fire for glass and porcelain retorts, the same directions are applicable to their management as to that of earthen or metallic retorts, though in the use of the latter less care is requisite. The proper position of the retort is in the centre of the furnace, Fig. 238, upon a crow-foot or support, Fig. 43, resting on the grate. The retort

having been previously charged, its beak is then adapted to the receiver, and the joints closed by lute. A very small fire is then ignited and increased as the retort has become warm, till it reaches to within a line or two of the level of the contained liquid. If the coals project beyond this point, the surface of the dry or upper part of the retort acquires a temperature so much higher than that of the substance which is being heated, that the difference may cause its fracture when particles are projected against it. A certain degree of heat in the upper part of the vessel is, however, necessary, so that the opposite condition—the condensation of vapor in it,—may not occur; and where the retort is heated unequally, it is sometimes necessary to place over it the dome of the furnace. For the same reason, also, when a retort is heated over a spirit or gas lamp, or by any other way in which the upper portion is exposed, that part should be covered with a dome. Fig. 258 exhibits such a one of earthenware for large retorts. A cone of pasteboard, Fig. 259, will answer better for

Fig. 258.

Fig. 259.



smaller vessels. The notch in the front allows its adaptation to the neck; but while adjusted so as to effectually protect the upper part of the retort from contact with air, it must be supported in such a manner that its weight, when great, shall not endanger the safety of the retort.

The addition of the fuel should be gradual, so that the fire may be only sufficient to gently boil the contained liquid. The coals should be first ignited to expel moisture; and when the operation is nearly completed, the fire must be skilfully managed. For greater safety, the glass retorts should always be coated exteriorly with a paste of refractory clay, or enveloped at the lower part with wire gauze.

When the Argand or gas lamp is used as the means of heating, the retort need only be arranged upon a support and brought over the flame, which is to be applied gradually at first, and slowly elevated until the glass has become heated throughout. To diffuse the heat and prevent the direct contact of the flame, the ring of the support upon which the retort rests, should have a wire gauze bowl, Fig. 260, for the holder.

Fig. 260.

Fig. 248 exhibits a retort properly located in a SAND-BATH, this being the mode of heating retorts for the distillation of volatile liquids, such as ethers and the like. The advantage of the sand-bath over the naked fire for heating glass retorts, particularly those of large size, is that it imparts a more uniform degree of heat, and prevents the possibility of fracture from sudden changes of temperature. The sand should be *fine*, and the layer, upon which the bottom of the retort rests, about an inch or two deep, according to the size of the retort. The sand surrounding the retort should only reach to the level of the contained liquid, and should be removed gradually as it evaporates.

To prevent condensation in the top, the upper portion of the retort may sometimes be advantageously covered with a woollen cloth.

When the operation is performed with a view to separate two liquids which boil at different temperatures, the retort must be either set in a bath which does not exceed the temperature at which the more volatile liquid escapes; or else, when otherwise heated, the temperature must be regulated by a glass thermometer, Fig. 120, entering the retort through its tubulure, and adjusted by a perforated cork.

When the boiling-points of different liquids are nearly equal, the density of one of them may sometimes be increased by the addition of some soluble matter, which, if both liquids are to be saved, can afterwards be readily removed.

Too sudden ebullition must, in all cases, be avoided, and the fire should be *gradually* increased, whether the heating vessel be of glass or metal. The only exceptions to this rule occur in the use of water or saline baths.

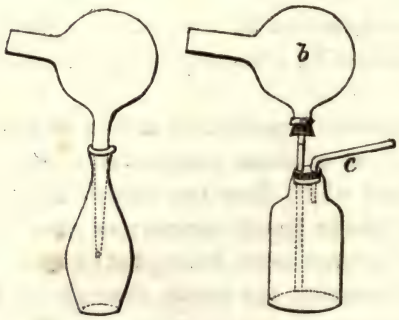
DISTILLATION OF LIQUIDS.—The STILL is the most convenient

implement for the distillation of large quantities of material. Retorts are more applicable to nicer operations.

The arrangement of a retort for the process of distillation is very analogous to that of a still. The body is the recipient of matter to be heated, and is the portion to which heat is applied; the beak is the condenser, and the glass receiver, the recipient of the distillate. The exit nozzle fitting upon the end of the worm and leading into the recipient, should never project so far as to dip into the distillate. If a globular receiver is not at hand, an ordinary glass bottle for retort distillations, or a carboy for those in the still, are excellent substitutes, as it is very easy to make the connection by using a curved adapter, Fig. 249, and adjusting it to the mouth of the receiver, as in all other cases, through a perforated cork.

Sometimes the receivers themselves are drawn out at the neck into a tube which enters a flask, as at Fig. 260, or else the tubulure is fitted with a perforated cork for the passage of a tube, which answers as well the purpose of a conduit. The flask

Fig. 261. Fig. 262.



which receives this tube is also fitted with a perforated cork, through which passes another tube *c*, Fig. 261, for the escape of uncondensed vapors.

The refrigeration of the receiver is readily accomplished by either of the arrangements shown at Figs. 247, 248, 250.

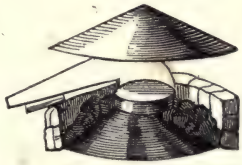
The uncondensed gases are allowed exit through a small glass tube, adapted to the tubulure in the top of the receiver, and leading upwards under a hood, or else downwards into a bottle of some fluid, which absorbs them, and thus prevents the contamination of the atmosphere.

It is of great importance that the vessels in use for distillation should always be free from foreign substances; and both the retort, still, adapter, and worm, immediately after each process, should be cleansed by repeated rinsings with water, so that they may be clean and ready for the next operation.

As the ebullition of certain liquids is attended with foaming and spirting, it is necessary to break the force of these sudden eruptions of vapor, by some mechanical means. This can be effected often by the addition of platinum scraps to corrosive liquids, and of fragments of glass to those which boil at low temperatures and are without action upon that substance. This precaution prevents damage to the vessel, and allows the boiling to proceed tranquilly. The use of the water bath obviates the necessity of this preventive, and is almost indispensable in the distillation of liquids holding in solution certain vegetable principles, which are sensitive to the decomposing influence of heat.

In distilling oil of vitriol in a glass retort, the deposition of sulphate of lead endangers the safety of the retort, and the purity of the distillate, by an explosive ebullition. To avoid this difficulty, Berzelius sets the retort one-third into the truncated cone of sheet iron, Fig. 263, strews sand around the edge of the cone, surrounds it with brick, and hangs a flat cone of sheet iron about a half inch above the retort. The retort is half filled with acid, and coals placed on the cone inside the bricks. Another method of Berzelius is to precipitate the lead salt by dilution with water, to concentrate the acid in a platinum capsule, and, finally, to distil in a dome-topped furnace, a quiet distillation being promoted by the introduction of platinum wire into the retort.

Fig. 263.



If the retort is tubulated, there is no difficulty in charging it neatly, because its contents can be added, without danger of spilling, through a wide-barrelled funnel; but when plain, it is necessary, in order to prevent the adherence of particles to the sides of the beak, to stand it on end, as shown in Fig. 264, and to fill it through the neck by means of a straight funnel-tube with its barrel reaching to the bottom.

The matters, if solid, should always be bruised or triturated to

powder and added portionwise. In this way the neck of the retort is kept clean.

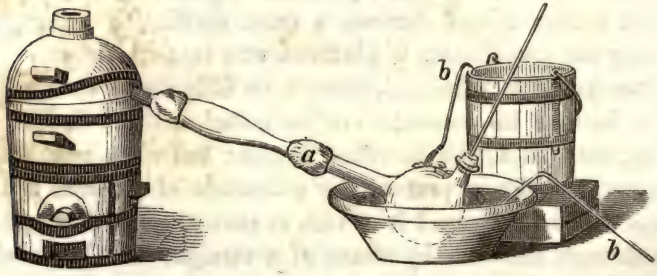
The joints of retorts and glass distillatory vessels may be luted with strips of muslin soaked in a solution of bone glue. Those of metallic vessels, with a dough of whiting and flaxseed meal, which, when dry, may be rendered still more impermeable, by a covering of muslin, prepared as above, with bone glue. When one vessel is adapted to the other by means of perforated corks, these latter should be payed over with wax or more economically with the flaxseed or whiting dough. If the distillate decomposes organic matter, the use of corks, flaxseed, and similar means, must be avoided, and the joints made tight by using apparatus, the connecting parts of which are nicely adapted to each other by ground joints.

Fig. 264.

All matters which readily generate very volatile products should be distilled over BATHS, of which those made of liquids are to be preferred. It is very easy to arrange the retort in a suitable vessel, by resting it upon a braided straw ring, Fig. 265, and steadying its neck in a clamp support. The beak of the retort should also be elongated by attaching it to a Liebig condenser, Fig. 267, so as to extend the cooling surface. If the distillate is readily condensable, the receiver may

Fig. 265.

Fig. 266.

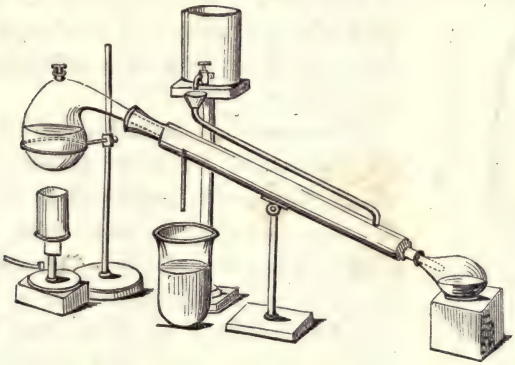


be kept sufficiently cold by a bath of cold water, as shown in Figs. 250, 266; otherwise the use of FRIGORIFIC MIXTURES

becomes necessary. The mixture should entirely surround the recipient, and as it becomes warm or liquefies, new portions must be added. If ice or other solid is used, the syphon in position, as shown at *b*, Fig. 266, will keep the pail constantly free from the liquefied excess.

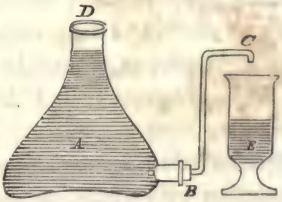
The proper arrangement of an apparatus with Liebig's condenser, is shown in Fig. 267.

Fig. 267.



In the distillation, particularly of essences and oils, the material, if it is ligneous, must be soaked, previous to its transfer to the still, in which it should be made to rest upon a cullendered diaphragm, Figs. 22, 27, to prevent contact with the heated bottom of the vessel. A proper vehicle is then added, and the operation continued by the application of heat. The water, or other liquid, and volatile matter are vaporized, and the two becoming involved pass over together. When these two products differ in density, as is commonly the case, a very convenient means of separating them as they pass over, is afforded by the Florentine receiver, shown in Fig. 268. A is the body of the recipient, and D its mouth through which the distillate enters. The tubulure B is for the reception of the beak (a curved glass tube), C. As soon as the condensed distillate reaches the receiver, the lighter body rises to the top, and there retains its position, and when the contained amount of the two fluids

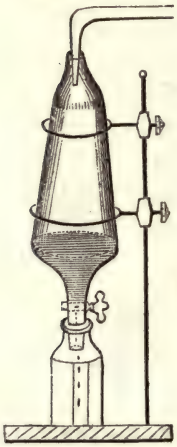
Fig. 268.



reaches the level of the mouth of the beak, the one which is most dense runs off. The level being kept thus constant, the lower stratum of fluid is separated from the upper as fast as any distillate comes over, leaving the lighter liquid to be emptied from the receiver after the completion of the process.

If the heavier product is the object of the distillation, as is sometimes the case, then the form of the recipient may be with advantage varied, as shown in Fig. 269. The stop-cock in the barrel allows its separation and discharge from the lighter body as soon as a sufficient quantity has subsided.

Fig. 269.



When volatile oils and some other bodies are obtained by the above process, the water which is generally employed as the vehicle, and which is separated as we have described, should be reserved, for being already more or less charged with volatile matter, it may be economically used in redistilling the same material, in case it should yield its product reluctantly. This repeated distillation of the distillate over the same material is termed *Cohobation*, and is resorted to necessarily, in many instances, that the material may be entirely exhausted of its volatile matter.

Rectification is the redistillation of the distillate, either alone or with some absorbent material to free it from water, acid, or other impurity.

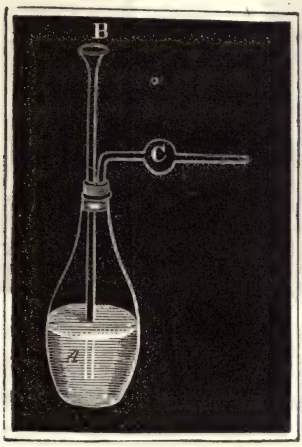
Distillation of Gases.—The term distillation cannot, in all instances, be applied with entire precision to the processes concerned in the manufacture of gases. But, as gaseous bodies, when intended to be retained, are usually prepared by modes precisely similar to those employed in liquid distillation, it has been thought proper to introduce their consideration in this place.

The generation and distillation of gases are generally made simultaneous operations. As their elasticity is such as to prevent condensation by ordinary means, they are either collected in solution with water, or other fluid, or in their gaseous state in gasometers. The arrangement of the required apparatus, though

bearing analogy to that for ordinary distillations, differs in many little but material points.

If the gas is readily evolved without the aid of heat, as in the case of hydrogen, carbonic acid, sulphuretted hydrogen, &c., the generator may be a simple flask A, Fig. 270. This flask is the

Fig. 270.



recipient of the material from which the gas is to be eliminated. The funnel-tube B, reaching nearly to its bottom, is the inlet of the acid, or other reagent, by which the action is to be produced, and the bent tube C is for the exit of the disengaged gas. An ordinary wide-mouth green glass bottle will answer the purpose excellently in most cases, as exhibited in Fig. 271, which shows an apparatus of this kind for passing gas through liquids, when its absorption is required,—as in the precipitation of solutions in analysis. When the generator is to be connected with a combustion or DESICCATION tube, as at Fig. 218, the bent tube can be removed. In this instance, and, indeed, with better results in all cases, the angular tube should be blown with a bulb in its centre for the reception of a plug of raw cotton, which intercepts the passage of liquid, and solid particles of foreign matters.

The exit tube is frequently divided into two pieces, and connected together by a piece of india-rubber tubing, as shown by Fig. 271. A flexible joint, B, is thus formed, and affords the convenience of giving the tube any required direction.

When, in particular instances, it is inexpedient to use the

funnel-tube, the generating bottle or flask may have the form presented by Fig. 272, which shows the exit tube issuing from a tubulure in one entire length, with two angular bends.

Fig. 271.

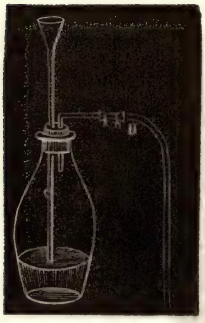
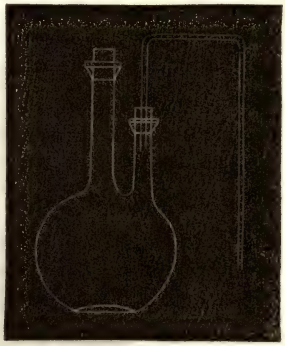


Fig. 272.



For certain operations, the bottle and delivery-tube are in one piece,—the part A, or mouth, forming the funnel tube; B the flask portion or generating chamber; and C the exit tube. This

Fig. 273.

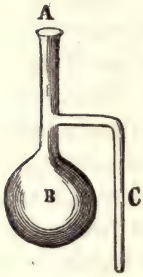


Fig. 274.

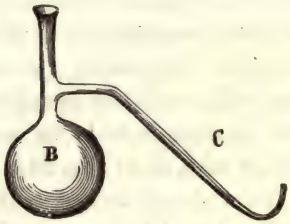


Fig. 275.

arrangement is adapted to experiments with corrosive gases, which act upon artificial joints and loosen them. When made of diminutive size, and with a long exit tube, as shown by Figs. 274, 275, they are very convenient for small experiments and testing, such as passing gas into test-tubes and the like.

The usual form of funnel-tubes is as shown by B, Fig. 270, which consists of a straight tube surmounted by a funnel. This funnel

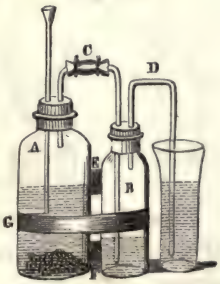
is sometimes made as at Fig. 299. To save the necessity of boring separate holes in the cork for the funnel and the exit or delivery-tube, Vogel combines the two in one piece, as seen at Fig. 276. The main stem is an ordinary funnel-tube *e d*, to which is joined a short piece of wider tube *a b*, with a lateral branch *f g o*. The tube *a b* being fitted to the cork of the generating flask, so that, when in place, it may reach the bottom of that vessel, is then ready to receive the acid through the funnel. The gas disengaged flows out through *a b* and its continuation *f g o*, thence it may be led into any course by a tube connecting with *o*, by a flexible india-rubber attachment.

Fig. 276.

The perforations in the cork must be only large enough for the transit of the tubes, and the joints must be perfectly tight. To render the cork itself impermeable, sealing-wax should cover both of its surfaces. This arrangement of the tubes obviates all liability of explosion. If condensation takes place in the interior of the generating vessel, the resistance from the funnel-tube being more feeble than that opposed by the water of the trough or receiving vessel, the air enters. So also, if from any cause the passage of the gas through the exit tube should be obstructed, its pressure upon the liquid in the generator forces it upwards through the funnel-tube, so that it may escape instead of being allowed to accumulate until explosion takes place.

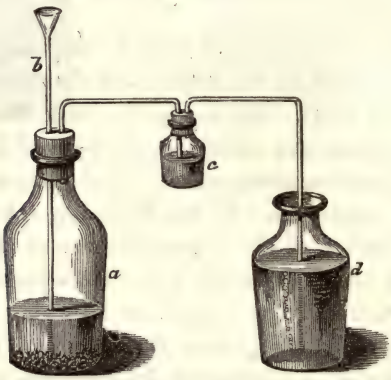
When it is desirable to have the gas free from impurity, an indispensable consideration if it is to be used in analyses, it should, previous to its entrance, be passed through a small quantity of water, or other fluid, which will dissolve out or chemically attract such foreign matter as might have an injurious effect upon the liquid to be acted upon. A suitable arrangement for such purposes, and one well adapted to the generation of sulphuretted hydrogen gas, is shown in Fig. 277; A is the bottle containing the proto-

Fig. 277.



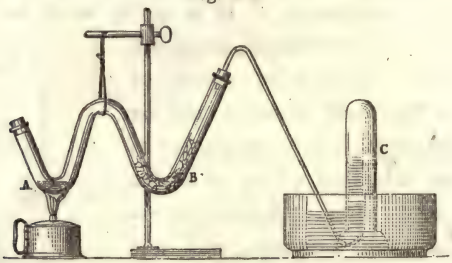
sulphuret of iron, water, and sulphuric acid, and provided with funnel and disengagement-tubes as usual, the latter plunging in the water of a smaller bottle B, from which a disengagement-tube D, nearly as high as that of the bottle A, issues, so as to lead the gas disengaged into a beaker or other vessel containing the liquor to be operated upon; but the first disengagement-tube C is in two pieces, united by india-rubber, and the bottles A, B, are connected together by a strong band of sulphurized india-rubber, or of gutta-percha G, so that the two bottles may be lifted at once as if they were in one, wedges of cork E E being forced between the two

Fig. 278.



bottles, so as to keep the strip of india-rubber G and the tube C properly adjusted. Fig. 278 exhibits the apparatus with stiff tubes, and a short vial, as the intermediate vessel.

Fig. 279.



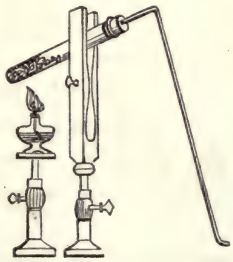
When heat is required to cause or to promote the elimination of a gas, the generating vessels may be either tubes, flasks, or retorts.

The facility with which glass tubes may be fashioned over the

blowpipe flame into any desired shape, renders them particularly applicable to small operations. Fig. 279 exhibits a tube-apparatus for the distillation of hydrobromic acid. It consists of a glass tube A B, to which is adapted a disengagement-tube conveying the gas under the bell C, filled with mercury. The bromine is placed at A, and at B are small particles of moist phosphorus intermixed with bruised glass. Gentle heat being applied at A, the vaporized bromine reacts upon the phosphorus and water, producing phosphorous acid, and disengaging hydrobromic acid gas, which passes over into the bell-receiver and displaces the mercury.

A test-tube, Fig. 280, fitted with a bent tube, serves very con-

Fig. 280.



veniently for generating small quantities of gas for analytic or even experimental purposes. Any other forms that may be needed will be suggested by the requirements of the process or the ingenuity of the operator, and can readily be fashioned after the instructions given upon GLASSBLOWING.

Another very convenient form of tube generator is that known as Marsh's Arsenic Apparatus, Fig. 281. It consists of an elbowed tube of Bohemian glass, fitted with a stop-cock and jet, the whole to be supported by a suitable stand or pedestal. The length of the tube may be sixteen inches, and its width three-fourths of an inch.

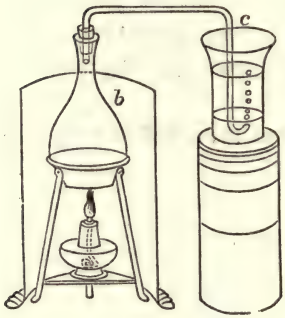
Fig. 281.

The elbow being charged with some pieces of purified zinc, the liquid containing the suspected compound is acidulated with oil of vitriol, and poured into the long leg. The arsenical combination becomes decomposed by the nascent hydrogen generated by the action of the sulphuric acid upon the zinc and water, and makes its exit through

the cock at the short arm, as arseniuretted hydrogen, which may be recognized, when ignited, by its bluish-white flame, and the appearance of the deposit upon a porcelain plate held over it. The stop-cock allows the facility of regulating or stopping off the supply of gas when required.

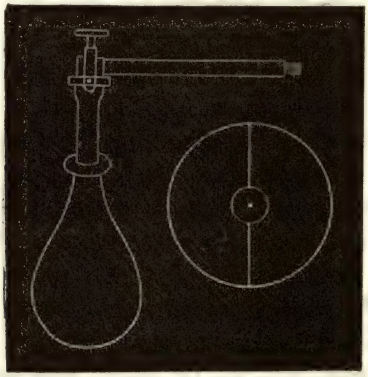
Next to the tubes, a Florence flask is the most economical vessel for conducting small operations. Fig. 282 exhibits one undergoing the process of being heated by a small spirit-lamp. The tripod upon which the flask rests, is surrounded by a tin plate screen of a foot in height, to confine the heat of the lamp. The exit tube conveys the gas into the beaker glass c, which contains the solution to be saturated. Flasks of very thin glass, and made uniform throughout, are blown expressly for this purpose. The exit tube is bent so that it may be used with bell glasses over a pneumatic trough, as in Fig. 279.

Fig. 282.



Retorts are only convenient when large quantities of material are to be operated upon. For those processes which require high furnace temperatures a metallic retort is needed. Fig. 282 exhibits one of iron, and another form has already been presented at Fig. 256. It is fitted with a very convenient coupling or

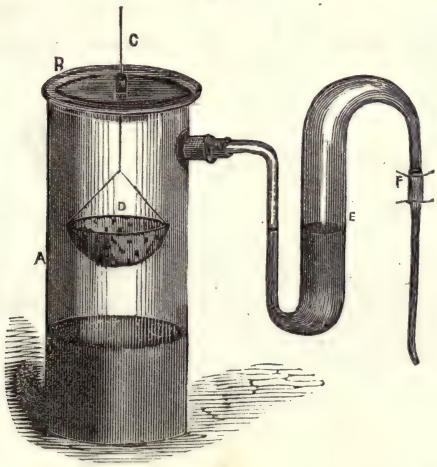
Fig. 283.



gallows screw, by which the neck may be connected with flexible lead or other exit pipes. The accompanying circular plate, in two pieces, serves both as a cover to the furnace and as a support for the neck of the retort to retain it in place.

The requirements of the laboratory are such, in respect to sulphuretted hydrogen and pure hydrogen gases, as to render necessary some convenient means for obtaining a constant supply of them, at any and all times, without the trouble and delay of arranging an apparatus in every instance. To this end several apparatus have been contrived, and we have already described one at p. 343. Another, known as Kemp's Generating Jar, is shown by Fig. 284. It consists, simply, of a tall glass jar A,

Fig. 284.

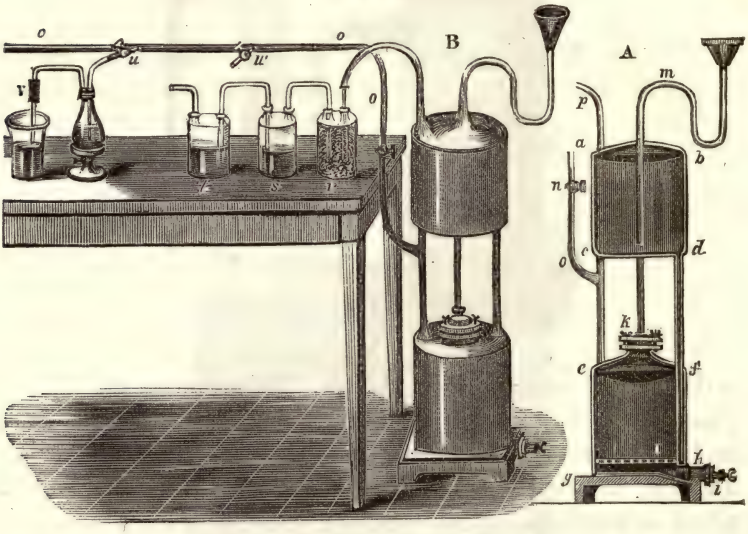


with a lateral tubulure near the top. Surmounting the top is a glass plate cover, bored in the centre, and ground on the under surface so as to form a close joint with the ledge of the jar. Through the centre hole passes a copper wire, to the end of which is suspended an earthenware basin or basket D. This wire is held in position by a cork tightly adjusted in the centre hole. The basket is the recipient of the zinc, sulphuret of iron, or other solid matter, to be used for generating the gas. E is a tube fitted to the lateral tubulure, and containing water for washing the gas in its transit to the delivery-tube F. This latter is connected with the former by means of a flexible caoutchouc tube.

The jar is kept filled with acid liquor to the height shown by the shaded part of the drawing, and when gas is needed, the cullendered basin D is to be pushed down into the acid by depressing the wire C, and kept immersed as long as a flow of gas is required. The evolution of gas may be discontinued at will, merely by raising the wire so as to draw the basin out of the liquor. If a rapid generation of gas is desired, it may be fully immersed below the surface, but not too deeply, for the acid liquor is weaker in the lower strata, after it has acted sufficiently long on the solid to convert a portion of it into a dense solution. A partial immersion, on the other hand, produces a gentle evolution of gas.

Another apparatus, for the same purpose as the foregoing, but on a more extended scale, is that recently devised by Fresenius, for disengaging sulphuretted hydrogen gas, and illustrated by the accompanying drawing. It is always ready for use, at a great

Fig. 285.



saving of material, and yet yields, from a single charge, a supply of gas sufficient for a month's service, with the least possible disagreeable odor.

It consists of two lead cylinders *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, Fig. 285, of equal size, all their joints being soldered with pure lead. Their diameter is 12 inches, and their height 13 inches. Resting upon

leaden feet, about $1\frac{1}{2}$ to 2 inches above the bottom, is a perforated leaden shelf I. An opening *k*, of about three inches diameter, and closed by a ground glass stopper, serves as the entrance for the sulphuret of iron from which the gas is to be generated. The glass stopper is screwed down with a greased leather washer between the two surfaces. An opening, for running off the residual sulphate of iron liquor, is shown at *s*.

"It may be seen in the section, A, that it is placed at a somewhat deeper part of the bottom *g*, *h*; the diameter of this opening is $1\frac{1}{4}$ inches. It is closed by means of a thick, ground, leaden stopper, pressed down upon its mouth by a screw. The arrangement of the filling tube *m* is sufficiently evident from the drawing, as is likewise that of the tube *d*, *h*, which is destined to convey the acid from the upper into the lower vessel, and from this into the former. It will be noticed that it extends into the deepened part of the bottom *g*, *h*, but does not actually touch. The tube *c*, *e*, is closed at the top, and, therefore, does not communicate in any way with the upper vessel. It is intended to convey off the gas disengaged in *e*, *f*, *g*, *h*, and with that view is furnished with a lateral tube *o*, which can be closed by the cock *n*. The use of the tube *p* will be seen below. The tube *q* is closed at both ends, and serves only as a support. These tubes are all of a half inch internal diameter, and should not be too thin in substance. When the apparatus is to be filled it is done in the following manner: about seven and a half pounds of melted sulphuret of iron, in small fragments, are introduced through the opening *k*, so as to rest upon the perforated shelf *i*, when *k* is carefully closed, *l*, of course, being likewise closed.

The cock *u* is then closed, and *a*, *b*, *c*, *d*, filled with dilute sulphuric acid, by pouring through the funnel first one and one half gallons of water, and then thirty fluid ounces of concentrated sulphuric acid. The air contained in *a*, *b*, *c*, *d*, escapes meanwhile through the tube *p*, even when it is connected with the bottles *r*, *s*, *t*. When now the cock *n* is opened, as well as one of the cocks *u*, the acid flows through the tube *d*, *h*, into the vessel *e*, *f*, *g*, *h*. At first air escapes from the tube *o*, and then sulphuretted hydrogen, as soon as the acid comes in contact with the sulphuret of iron; after a time all the air is driven out. As seen in B, the tube *o* is bent and carried along horizontally.

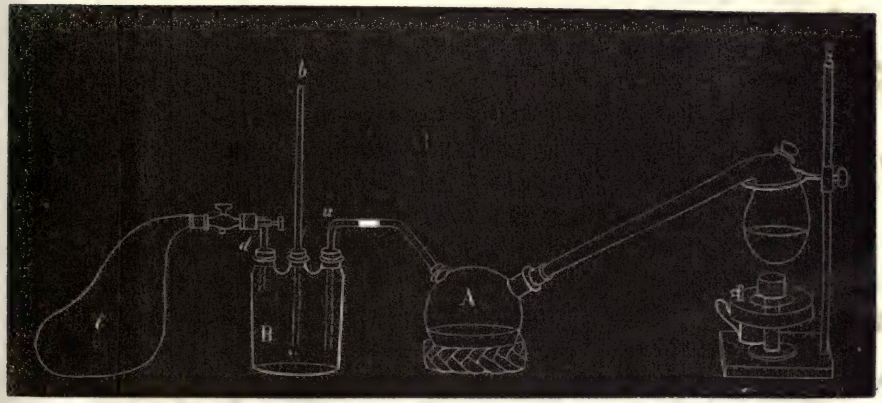
To it are attached as many ordinary brass cocks *u*, *u*, as may be desired. They are connected with washing bottles in the manner represented, by means of a piece of vulcanized caoutchouc tube. When the cock *u* is opened, as well as the cock *n*, a stream of gas, of any desired amount, is obtained, which continues perfectly uniform for days. When the cocks *u*, *u*, are closed, the gas disengaged in *e*, *f*, *g*, *h*, presses the acid upwards through the tube *h*, *d*; and when the sulphuret of iron is no longer immersed in the acid the action ceases. This, however, does not take place instantaneously, for there is always some acid left adhering to the sulphuret, and small fragments of the latter fall through the holes of the shelf, and maintain the action for a certain time. Since the gas can no longer escape through *o*, it presses the liquid in *b d* upwards, bubbles up through the acid contained in *a*, *b*, *c*, *d*, and escapes through *p*. In order to prevent this gas from being lost and contaminating the air, the bottles *r*, *s*, *t*, are attached; *r* contains cotton-wool, which supplies the place of water in an ordinary washing bottle, as water would readily run back into the apparatus; *s* and *t* are charged with solution of ammonia in such quantity as to be entirely contained by either bottle; for as the stream of gas is here intermittent, the liquid may be forced backwards and forwards from one bottle to the other. A constant supply of sulphuret of ammonia is thus obtained as a by-product. When at last the disengagement of gas ceases, the acid has been all consumed, but not the sulphuret, which is equivalent to double the above quantity of acid. It is therefore necessary to run off the solution of sulphate of iron. This is done in the following manner:—All the cocks *u* are closed, *n* left open, and a dish placed under *l*, which is opened, and then one of the cocks *u* opened. As soon as the air enters, the liquid runs off rapidly, and when it is all removed, the edges of the opening *l* are washed with water; it is again closed, and another quantity of acid added as before. It is not advisable to use stronger acid, for in that case the sulphate of iron would crystallize. The brass cocks do not suffer at all from the sulphuretted hydrogen, and the apparatus answers all reasonable expectations."

Collection of Gases.—Gases are either collected in the aeriform state or else in solution. When generated extemporaneously,

merely as precipitants of some solution, they are passed through the liquid contained in a beaker glass, as at Fig. 282, and Fig. 277, a tightly stretched paper cover being in general all that is required to confine the unabsorbed excess in the vessel.

If a liquid, as well as a gaseous product, is generated simultaneously, then the arrangement of the apparatus may be as shown in Fig. 286. The use of this may be well illustrated by a

Fig. 286.



reference to the manufacture of nitrous oxide gas. The nitrate of ammonia, the material from which it is generated, is placed in the retort, the beak of which is adjusted by means of a perforated cork, to the tubulure of a globular receiver A. This receiver in its turn is connected by bent glass tubes, rendered flexible by a caoutchouc joint, with a Wolffe's bottle B. The latter, deriving its name from that of the inventor, consists of a bottle, the size of which may vary with the extent of the operation, having in this instance three tubulures, each of which is fitted with a perforated cork for the passage of glass tubes. The first tube *a*, Fig. 286, conducts the gas from the receiver, and the central tube acts as a safety valve. The gas cannot escape through it, but should condensation ensue within the bottle, the external air rushes in and prevents the liquid from running over into the recipient or next bottle, if there are two connected, by reason of absorption. The third tube *d* is the exit tube for conveying the gas directly into the recipient, which in this case is a caoutchouc bag *e*.

The retort, receiver, and Wolffe's bottle having been connected

together, and the joints hermetically closed, heat is then gradually applied by means of the spirit Argand lamp. The eliminated gas passes over into the receiver, there deposits the aqueous vapor with which it is involved, and continues on to the Wolffe's bottle containing water, in its transit through which it parts with the rest of its aqueous vapor, and its other impurities, and ultimately reaches the exit tube *d*. If the gas is to be received into caoutchouc bags, Figs. 171, 286, and pages 252, 351, for inhalation or other purposes, the connection may be made directly, as seen in the figure, by means of a gallows screw, which allows an empty bag to replace another, as may be necessary. If the bags are intended as reservoirs for the preservation of the gas, their necks are fitted with gallows screw stop-cocks and connecting nipples.

If the gas is to be conducted into a Pepy's gasometer, as at Fig. 301, or under a bell-glass over a pneumatic trough, as at Fig. 294, then instead of the stop-cock there must be a flexible bent tube, of shape similar to that attached to the Fig. 271, adapted to the third tubulure of the bottles.

Lead pipe of a small bore may be used as a conduit when the generated gas is not corrosive, but india-rubber tube is preferable. The gallows screw then becomes the proper mode of connection.

To favor the condensation of the aqueous impurity of the gas, the globular receiver should be kept cool during the distillation. So also the Wolffe's bottle must be surrounded by water, or a cooling mixture, when the gas is very volatile, otherwise the elevation of temperature, which generally occurs, may cause its dissipation.

When two or more gases are generated simultaneously, they may be separated by the presence in the receiver of an appropriate liquid, which is a solvent of one, but not of the other of them. Thus oxygen may be freed from carbonic acid by passing the mixture through a solution of caustic potassa, which absorbing the acid becomes carbonated, and allows the transit of the purified oxygen. This mode is adapted for this and other purposes in organic analysis, the requisite apparatus being a five-bulbed white glass receiver of the form shown by Figs. 287, 288. Its arrangement for the purpose is given in Fig. 139, *a* being the com-

bustion-tube, in which the substance to be analyzed is introduced after its mixture with oxide of copper or chromate of lead, from

Fig. 287.

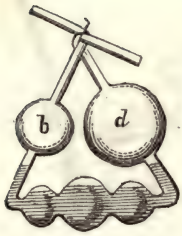


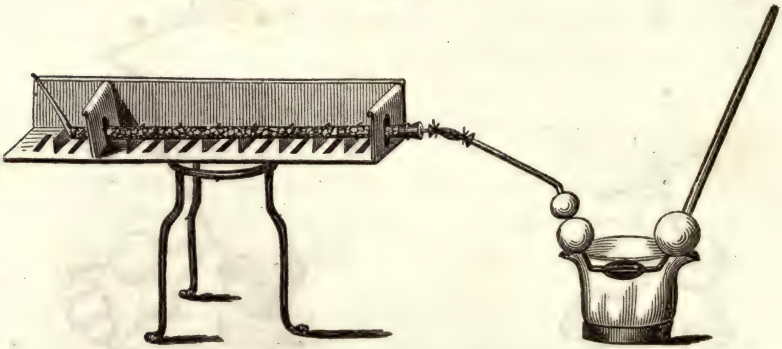
Fig. 288.

which it obtains the oxygen necessary for its combustion. The figure represents the tube in its position, during the analysis, in the trough-shaped furnace of sheet-iron, in which it is heated by being surrounded with ignited charcoal. By means of a perforated cork, the combustion-tube is connected with the tube in which the water produced by the combustion is condensed. It is filled with chloride of calcium, in order to absorb all the vapors from the carbonic acid, which passes through it into the apparatus *m r p*, through which it would be forced, were it not absorbed by the solution of caustic potassa contained in the lower bulbs. After the completion of the combustion, the carbonic acid which remains in the combustion-tube is extracted from it, by breaking off its pointed extremity and applying suction to the other end of the potassa apparatus at *p*, by which air is drawn through the whole apparatus, and the carbonic acid absorbed by its passage through the solution in the potassa bulbs. The weight of the water and the carbonic acid, is obtained by weighing the chloride of calcium tube and the potassa apparatus before and after the combustion. For this purpose, each may be conveniently suspended to the supplementary pan, Fig. 76, of the analytic balance, p. 112.

Another form of receiver, for similar operations to the preceding, is shown by the annexed drawing.

These two operations illustrate the generation of gases by destructive distillation; but the receivers which are used in them, are equally applicable for the collection of gases generated in

Fig. 289.

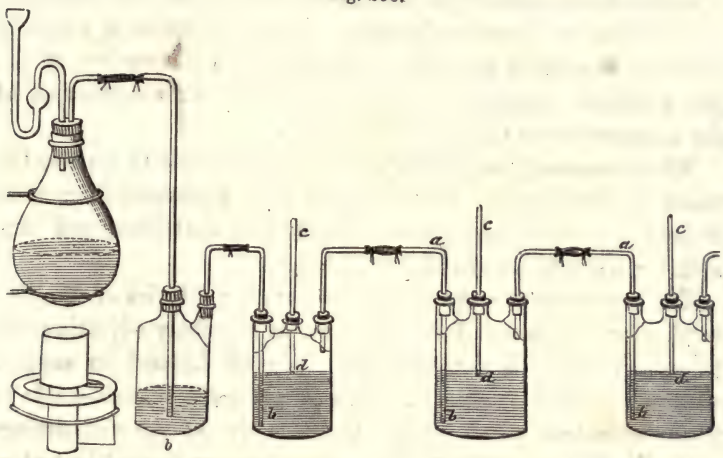


the cold; the object of the bulbs being to present a larger extent of liquid surface to the gas. Fig. 288 illustrates the manner in which these bulb-receivers may be filled with absorbent liquor without inconvenience to the operator. The lower end being placed in the liquid, and the upper connected by a cork to a bent tube, suction is then applied to the latter by the mouth until sufficient liquid is drawn in, after which the suction-tube is disconnected.

In the instance we have been referring to, the Wolffe's bottle is used for the purpose of retaining watery vapor or other impurities in its contained fluid. Its most common employment, however, is when the gas itself is intended to be preserved in solution in water or other fluid. For this purpose, the number of Wolffe's bottles is often increased to three or more, which are connected together by tubes with flexible joints. In this manner, any gas that has remained unabsorbed by the liquid in the first bottle, is successively exposed to the dissolving influence of that in the others, until it becomes entirely liquefied. The Wolffe's bottles, the form of which is sufficiently explained by the drawing, may, in many cases, be well replaced by wide-mouthed jars or bottles, with two or three perforations in their corks, and which may be made to answer all the purposes of the more expensive apparatus.

Fig. 290 represents an apparatus for the generation and absorption of gas; *a* being the heating vessel, the contents of which

Fig. 290.



should fill only half its capacity, so that they may not, upon too sudden reaction, run over into the recipient; *b* the recipient, either for the condensation of aqueous vapor, or the abstraction of impurity by a contained liquid, and the three Wolffe's bottles, half filled with water, the receptacles of the eliminated gas. As the volume of the liquid in the Wolffe's bottles increases proportionably to the amount of gas received and dissolved, they should not be more than half filled at the commencement. So also the intermediate receiver should have but a very shallow depth of liquid, else it will take up gas as well as the impurities, and thus cause a loss. The water in the first bottle is the first to become saturated, and all the gas which is not absorbed passes over into the second and third bottles, through the delivery-tubes and transit-tubes *b*, *a*. This arrangement is that usually adapted for the distillation of acid, ammoniacal, and other gases, which are condensed by solution.

The tubes must be adjusted to the tubulures by corks (see Chap. XXXI), in such an exact manner as to form an air-tight joint; and the connections of the glass tubes should be flexible, and formed of india-rubber tube. The tubes *c* passing down through the centre of the corks and ending at *d*, just below the

level of the liquid in the bottles, serve for admission of air, when from any cause the internal pressure may become diminished, and are thus a safeguard against the liquid running back by the force of external atmospheric pressure, from the last bottle to the third, second, first, and even to the flask. This diminution of external pressure sometimes proceeds from a prompt absorption of the gas, a sudden stoppage in the delivery of it, or a depression of the temperature in the generating flask.

When necessary, any other liquid may be made to replace the water in the bottles. For example, aqua ammoniæ when it is desired to make a chloride or carbonate of that base, and lime milk for the solution of chlorine, &c. &c.

The inconvenience and delay in arranging a series of Wolffe's bottles for distillation, from the trouble of nicely adjusting the tubes and corks to the tubulures, induced Letorel to suggest a more expedient substitute, which is particularly serviceable in those operations which would be destructive of the cork-fittings of the Wolffe's apparatus. The connections are formed by water-joints, and the apparatus, comprising three glass cylinders, is represented, in vertical sections, by the three diagrams following:

Fig. 291.

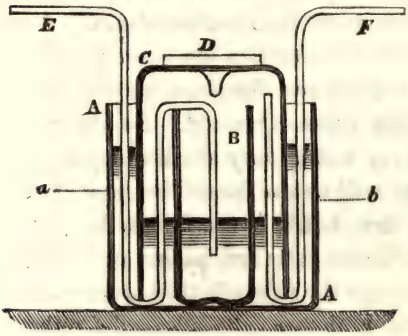


Fig. 292.

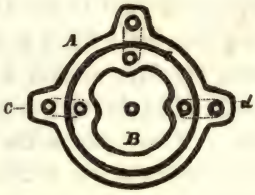
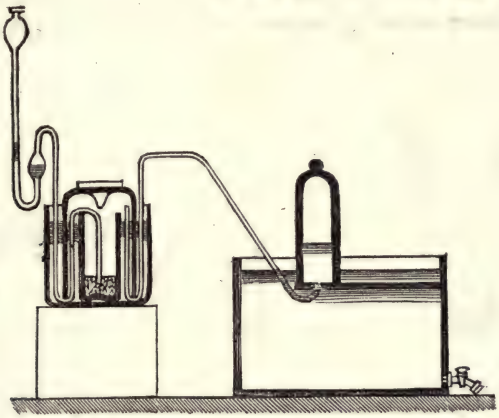


Fig. 293.

"The outer and inner cylinders A, B, have, severally, three grooves perpendicular to their base, and at corresponding points of their circumference, but in opposite directions. The intermediate cylinder C is plain, and is inserted within A over B. The liquid used to shut off communication with the exterior air is placed in the outer cylinder, and the liquid to be brought in con-

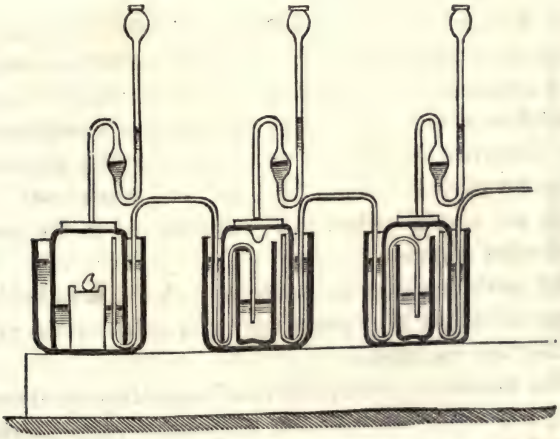
tact with the gas is placed in the inner vessel. The gas is conducted into B by the bent tube E, and the unabsorbed portion escapes by the tube F. Both these tubes fit in the pairs of opposite grooves. The third pair of grooves is for a safety-tube, Fig.

Fig. 294.



293, if requisite. The mode of connecting a series of these vessels will be sufficiently evident from the wood-cut. This arrangement may likewise be employed for generating gases, as shown in

Fig. 295.



Figs. 294 and 295. The liquid used for the hydraulic joint must be adapted to the nature of the operation. In the preparation of

carbonic acid or the bicarbonates, water will answer. For other purposes, mercury, solutions of chloride of calcium, of caustic alkali, &c., may be used. The cylinder C must be loaded with a sheet of lead in order to keep it steady."

For micro-distillations, the Wolffe's bottle may consist of a U-shaped tube, bent as seen in Fig. 296. These condensers can be formed into a series by means of corks and bent tubes, as shown

Fig. 296.

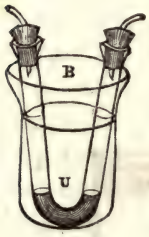
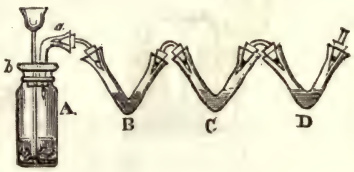


Fig. 297.



by Fig. 297. They are very convenient for minute experiment, and admit of the use of either liquid or solids, as agents for absorbing gases. The condensing material occupies the bend B, C, D, if liquid, as indicated by the shaded portion. In the use of a solid absorbent, it should nearly fill both legs of the tube. Very small and little bottlings, with two and three tubulures, are also used for delicate operations.

When the gas is to be generated by reaction of liquid upon a solid, the latter must be put into the flask before the stopper and tube are adjusted. The liquid can then be added through the S tube, as often as it is required to continue the disengagement. If the gas is heavier than the solvent liquid, the disengagement-tube need dip but slightly beneath its level; and *vice versâ*.

There are several points to be remembered in the generation and collection of gases.

1. All gases owe their existence as such to a certain elasticity, by reason of which they press upon the sides of the vessels in which they are enclosed.

2. The tension or elastic force of a gas is proportional to its quantity: it augments with the temperature, and decreases by refrigeration.

3. The atmosphere weighs upon all bodies, its pressure being

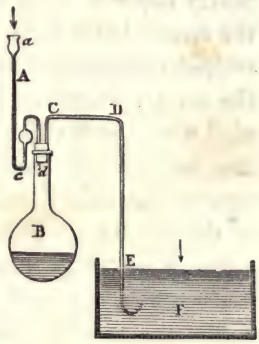
usually equal to the weight of a column of water 34 feet high, or of a column of mercury 30 inches.

4. That liquids (in equilibrium) press equally in all directions.

These facts, therefore, render necessary the use of the safety-tubes *c*, *c*, *c*, Fig. 290, and Welters tube, Figs. 298, 299.

Safety Tubes.—When, in the course of distillation, a momentary suspension of the heat or generating impulse causes a partial vacuum in the heating vessel, the liquid into which the disengagement-tube dips is forced by the pressure of the atmosphere into its bore, and ultimately into the vessel itself.

Fig. 298.



This entrance of liquid into the generating vessel may result also from its sudden cooling, by the entrance of cold water, or by other means.

The results of this absorption are sometimes the fracture of the vessel, and more frequently irreparable injury to its contents. To obviate these inconveniences, we use a safety-tube, the usual forms of which are shown by Figs. 250, 298, 299. The first, which is called an S tube from its similarity to that letter, is most used, but either of them may be employed in the following manner. If the generating vessel has only one aperture, its cork, having been tightly fitted and rendered impermeable by coatings of sealing-wax or other cement on its upper and lower sides, is then to be perforated with two holes, one for the transit of the S tube, and the other for that of the exit tube. The tubes being tightly adjusted in the holes, as shown in Fig. 298, and the cork fitted to the mouth of the generating flask, a quantity of water or sometimes of other liquids, as mercury, is poured into the S tube. When, during the process, the level is stationary in the bulb B, and in the part A of the tube, the apparatus is hermetically closed. If, however, a condensation of vapor takes place in the interior of the flask, the external pressure of the atmosphere weighs alike upon the liquid F of the

Fig. 299.

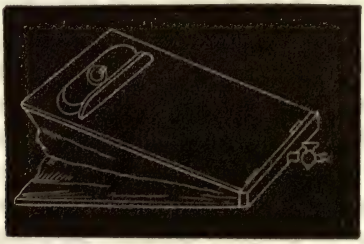
trough, and that in the S tube; but as the latter offers the least resistance, the air first makes its contained fluid advance towards the flask, and then enters in bubbles into it, thus preventing the absorption of liquid from the trough or receiver.

If mercury is used, its relative density to water must be remembered, and the column of metal in the curve should be as low as possible. As a column of mercury requires one of water nearly fourteen times its height for its support, it follows that if the former is too high, the gas passes back more rapidly into the recipient during condensation from the disengagement-tube than the air traverses the metallic mass in the S tube. Mercury is used when the Wolffe's series comprises a number of bottles; so that the opposing force of the contained liquid may not be sufficient to cause the disengagement of the gas through the S instead of the exit tube. When operating with a mercurial trough, the S tube, Fig. 299, without a bulb, is used. The quantity of metal which it should receive must, however, be such that the pressure of the gas will meet with as strong a resistance from it as the liquid in the trough. When flasks are replaced by retorts, the latter should be tubulated, so that the safety-tube may be adapted to its tubulure by means of a perforated cork.

If the retorts are necessarily plain, as in certain distillations by furnace heats, then the safety-tube can be attached to the disengagement-tube E, Fig. 307, over the blowpipe flame. The liquid is introduced at H I. This kind of tube, known as Welter's, is very fragile, and requires careful management and handling.

Gasometers.—When the eliminated gas is to be preserved free from air, in large quantities, for laboratory purposes or transpor-

Fig. 300.



tation, it is received in gasometers. Gas bags, made of caoutchouc, are very convenient for storing gas for use, and have already

been mentioned at p. 251. The annexed drawing presents the apparatus separately. It is placed between two hinged boards, with a hole in the centre of the joint for the passage of the neck of the bag and its cock, by which it is coupled with the generating apparatus, as seen at Fig. 171. The upper board is fitted with a groove for the reception of a heavy iron upright, which constitutes the pressure by which gas is drawn from the bag as may be wanted.

Pepy's Gasometer.—The most convenient gas-holder is that known as Pepy's, Fig. 301. It consists of a japanned zinc hollow

Fig. 301.

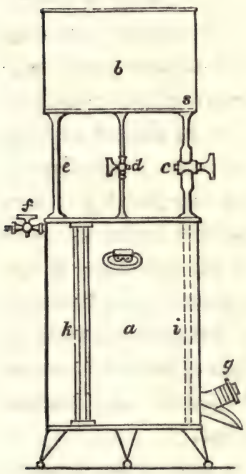
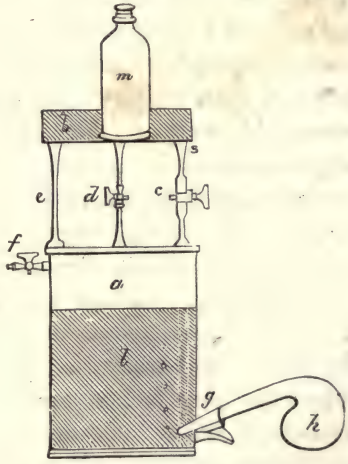


Fig. 302.



cylinder 16 by 12 inches, surmounted by a trough *b* of 9 by 12 inches, making the total height of the apparatus, including that of the supports, three feet. Near the base of the cylinder is a lateral gulley, placed obliquely, and cut with a thread to receive a screw plug, which closes it hermetically.

The tube *d*, supporting the centres of the vessels, and fitted with a cock, allows a communication between the reservoir and trough. A second tube *s c i*, at the side, also fitted with a cock, passes from the upper cylinder into the lower, and descends, as shown by the dotted lines, to within a few lines of the bottom. The stem *e* is merely a support, and serves no other purposes. The coupling and stop-cock in the side near the top serve for connection with a jet, or for fitting on a bag or bladder. The

glass gauge *k*, graduated into cubic inches, is adjusted firmly and hermetically by means of sockets at the top and bottom of the cylinder, and serves to indicate the level of the internal water. To prevent fracture, it is embedded in a framework of the same metal as the gas-holder.

The manner of using the apparatus is as follows:—close the mouth *g*, and fill the reservoir with water. For this purpose the water is poured into the trough *b*, and allowed to run down through the opened tubes *d* and *c*. The cock *f* being also opened, the confined air escapes as the water enters, and in proportion as the reservoir *a* is filled, the water rises in the tube *k*, and hence the latter will indicate when it is full. As soon as this occurs, and water runs through the pipe *f*, the cock of the latter must be closed, and the residual air allowed to escape through the still open tube *d*. If, upon gently shaking the vessel, no more bubbles appear, then all the cocks are to be closed, and the apparatus mounted over a tub, of diameter some six inches or more greater than that of the gasometer, and the gullet *g* is then opened. As the highest part of the edge of the inner aperture of this gullet is lower than the lowest part of the edge of the outer aperture, by a half inch or more, the water cannot escape, unless the air simultaneously finds access, inwards, from above, by leak-holes or otherwise. If, after the gush of a small portion when the plug is first removed, there should be any further leakage, it will be indicated by the gauge-tube.

All being tight, the beak of the retort, or end of the conduit-tube of the generating vessel, is introduced into the gullet, as shown at *h*, Fig. 302. The eliminating gas entering the receiver, displaces the water, which escapes at *g*, and falls into the pail beneath. As soon as the vessel is full, which will be known by the examination of the gauge, or when a sufficient quantity has been collected, the disengaging-tube or beak is withdrawn, and the gullet closed with the plug.

If it is desired to fill a gas-bag from the reservoir, it must be fitted with an appropriate cock and nipple for connecting with the coupling cock *f*, and the pressure of the water with which the trough *b* has been partially filled, should be made to act upon the gas by opening the cock *c*. So also when the gas is to be transvased into bell-glasses, these latter are filled with water to

displace all air, inverted, and then brought directly over the opened tube *d*, as shown in Fig. 302. As the water enters from the trough through the tube *c*, gas escapes into the jar by the exit pipe *d*. When the vessel is filled, communication must be shut off by closing the cocks.

When a greater pressure is required than can be given by the water contained in the trough, it can be obtained by means of a long-barrelled funnel *o*, Fig. 304. When this is screwed by its threaded nipple *p*, into the socket *s*, Fig. 302, and filled with water, there is a pressure of nearly six feet. By abridging the length of the barrel to *q*, the pressure is diminished to a little less than four feet. When two of these gasometers, filled the one with oxygen and the other with hydrogen, are united by means of a double jet, Fig. 303, connected by its branches *a b* with the cocks *f* of the reservoir, they form what is called the hydro-oxygen or COMPOUND BLOWPIPE described at p. 170.

Fig. 303.

Mercurial Gasometer.—When the eliminated gas is soluble in water, or altered by contact with that liquid, it may with propriety be collected over mercury. For this purpose Pepy has contrived the arrangement shown in Fig. 305, which obviates the expense and inconvenience of filling the cistern with mercury. It is made of iron, and consists of a bell A A B B, which has a cock C at its summit, and which is immersed in a cylindrical iron cistern M N O P. This cistern is the reservoir for the mercury, but in order that as little as possible may be used, an iron core D E occupies its centre, and allows an interval between it and the sides of the cistern only sufficient for the jar and mercury to make it tight. A glass tube *a b* cemented tightly to the top of this inner cylinder, traverses it and serves as a conduit of the gas into the bell, which is maintained in a vertical position by a movable elbow adjusted to the frame of the apparatus.

A cock *c* is adjusted to the tube *a b*, and puts it in communication with the eprouvette or small inverted bell F, placed upon a dish containing mercury.

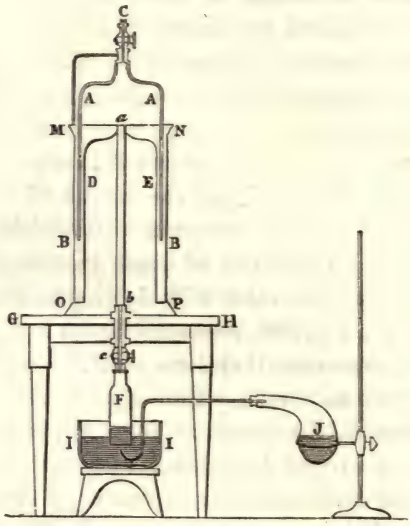
In using this gasometer, the cavity M N O P is filled with mercury, the cocks C and *c* are opened, and after the bell has

been pressed down to its full extent in the metal, the cock C is closed.

The disengagement-tube is then introduced under the mouth of the eprouvette, and the generation of the gas proceeded with.

Fig. 304.

Fig. 305.



Each bubble as it enters the bell elevates it proportionately; and when it has received a quantity equivalent to the volume of the capacity of the tube and of the eprouvette, the cock C is to be opened again and the bell depressed. The greater part of the gas which has entered, and the air with which it is mixed, is thus forced to escape. A repetition of this manœuvre two or three times will insure the entire expulsion of the air; when the portions of gas given off can be collected and preserved for use. When the bell is full, the cock *c* is to be closed and the retort J removed.

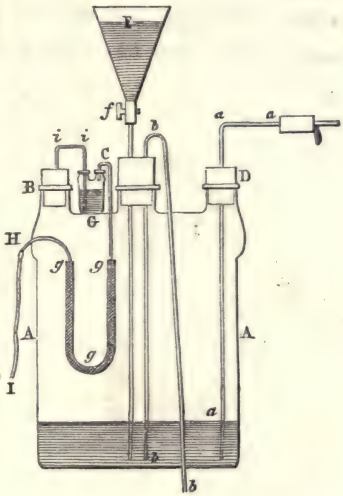
To transvase any portion of the gas that may be wanted for use, it is only necessary to put the tubulure C in communication with the vessel in which it is to be received, by opening the cock, and then to depress the bell in the mercury.

A scale graduated upon the side of the bell will allow an estimation of the volume expended.

Deville's Gasometer.—This apparatus, constructed upon the same principle as Marriot's vase, is most used in organic analysis.

Fig. 306 exhibits the arrangement. A A is a tubulated bottle filled with water; and *a a a* is the tube for disengaging the gas from the generator. Each bubble of gas displaces an equal volume of water, which is conducted off by means of the syphon *b b b*, and the process should be continued until the expulsion of all the water, save just enough to fully close the orifices of the tube.

Fig. 306.



When the gas is to be disengaged for use, fill the funnel E with water, and open the cock *f*. The pressure of the water descending into the flask forces the gas into the tube *i i*.

A flexible tube H I can then be adapted to the orifice of the vessel into which the gas is to be introduced.

This gasometer is especially employed for holding oxygen to be passed over oxide of copper in tubes, after organic analysis; and to remove all carbonic acid that it may contain, it is passed through a flask containing an aqueous solution of caustic potassa.

The small bottle C contains the concentrated sulphuric acid, and the tube U potassa in one branch, and chloride of calcium in the other.

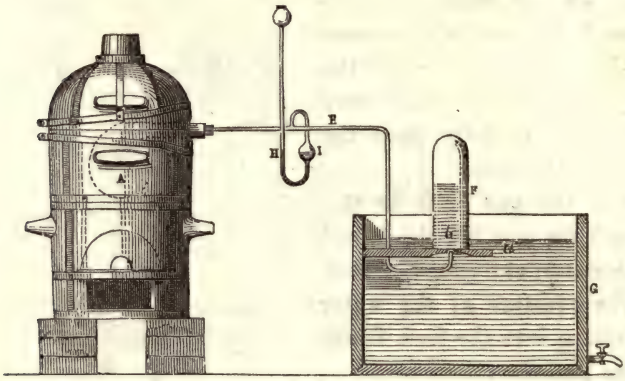
If the oxygen is kept in this holder for too long a time, it becomes altered and contaminated with atmospheric air.

Pneumatic Troughs.—In most manipulations with gases, particularly when they are required for immediate use or for temporary purposes, they are collected over the pneumatic trough. As the bell glasses into which they are to be received must first be freed from contained air, it is necessary to immerse

them in an appropriate liquid. Water and mercury are the two fluids almost universally employed, the first being used for all those gases which are not soluble in it, and for some which are only so in a slight degree, and the latter for those which are absorbed by water, and which exert no chemical action upon the mercury. Hence the distinctive terms, *water* and *mercurial trough.*

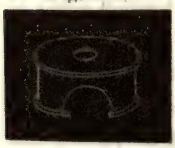
Water Trough.—A wooden pail, square or oval, with a little management, can be converted into a most convenient water

Fig. 307.



trough, G, Fig. 307. It should be of capacity sufficient to allow the thorough immersion of bells of any size required for experiment. One of a foot in depth, sixteen inches in length, and ten inches in width, will be very suitable,—a vessel G of this size fulfilling almost all the requirements of an experimental laboratory. Near to the top, in the interior, should be lateral flanges for the support of a sliding shelf *a*. This sliding shelf should have sufficient surface for the support of several bells or jars, F, at a time, and may extend over half of the trough. It is perforated with holes for the reception of the beak of the disengaging vessel, as seen at *b*, Fig. 306.

Fig. 308.



A very convenient water-bath for the collection of gases may be formed of a deep earthenware dish, or other vessel in common use, by the addition of the bee-hive shelf, Fig. 308. This shelf, generally made of porcelain, is a substitute for the shelf of a regular trough, and serves for the support of the bell glasses or

other receivers. It may be two inches in diameter and one inch high, for a dish one foot wide and two inches deep, and proportionally larger for one of greater dimensions. The disengagement-tube enters the semicircular opening at the base, and delivers the gas into the receiver by its curved end protruding through the hole in the centre. Part of a loaded wooden box, a metallic support, or other extemporaneous arrangement, may, in many cases, be so adjusted to take the place of the common, or the bee-hive shelf, and to answer every useful purpose.

It is indispensable that the trough should be made thoroughly water-tight, and should be well hooped. For further protection, it might be covered over with several coats of paint. Leakage being thus provided against, the vessel may be used upon either the operating or centre table. The stop-cock near the bottom allows the exit of the water when it has become dirty, acidified, or otherwise unfit for use.

The level of the contained water must always be half an inch or more above the top of the shelf. When the bell is to be charged, it is first completely immersed in the water, so as to expel all contained air, then taken up by the knob, raised to a vertical position, and carefully slid along with its mouth in the water to the shelf, and placed immediately over the hole through which the disengagement-tube enters. As the gas bubbles up into the bell, the water is displaced, and when it is filled, it can, if necessary, be drawn aside and replaced by another. So the process is continued until all the gas generated has been collected in bells.

As the first bubbles of gas eliminated are contaminated with air, they should be rejected; consequently the beak of the disengagement-tube ought not to be brought under the bell receiver until the gas commences to pass over freely.

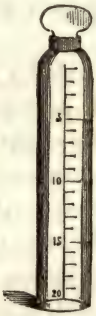
Bell Glasses—Gas Jars or Receivers.—The arrangement of an experimental laboratory is incomplete without a series of bell glasses, varying in size from a gill upwards to one gallon. They should be of glass, preferably of white glass free from lead, and made so as to combine strength and neatness, and should have a knob at the summit for convenience of handling. The rim of the mouth must be ground perfectly smooth and level, so that when resting upon an unground glass disk or an even-bot-

tomed plate, the joint may be tight. Fig. 309 exhibits a plain jar for ordinary uses; and Fig. 310 a similar implement tubu-

Fig. 309. Fig. 310. Fig. 311.

lated at its summit, and closed with a glass stopper. This opening not only allows the facility of forming connections with other apparatus, but also that of filling it readily with liquid merely by depressing it, while unstopped, vertically in the water trough. The air escapes through the tubulure in proportion to the rise of fluid in the receiver, which when full is to be stoppered and placed upon the shelf to receive the gas. Sometimes the tubulures are fitted with stop-cocks, as seen at Fig. 311, which add to the convenience of the jars in many operations, and particularly when it is desired to pass a measured quantity of gas from the receiver

Fig. 312. Fig. 313.



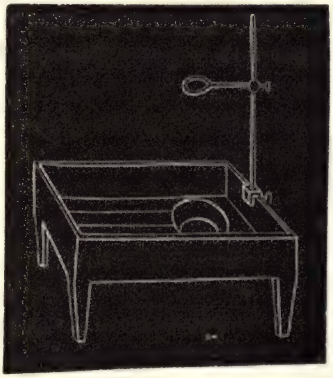
into another vessel attached as heretofore described at p. 147. For this purpose the bell must also be graduated as seen in Fig. 312. Fig. 313 presents a graduated bell-tube.

If the vessel into which the gas is to be received is a bladder instead of a glass bell, it must be fitted with a coupling cock, freed from air as much as possible by compression with the hands, then connected with air-pump or syringe, and completely exhausted by suction. The cock is then closed, the bladder detached from the syringe, and adapted by its coupling to the cock of the bell. Communication being opened, the gas passes into the bladder upon the depression of the jar.

By grinding the surface of the ledge very accurately, and fitting the mouth of the bell with a ground glass disk, which, by the intervention of a little grease, may form an air-tight joint, gases may be retained unaltered for a limited period. The syringe, Fig. 47, is made so that it may be used both vertically and horizontally.

The Mercury Trough.—The high cost of mercury renders necessary an economical construction of the trough in which it is kept. Fig. 314 exhibits one of convenient form. It consists of a well-japanned cast-iron trough, twelve inches long, seven inches wide, and two inches deep. The bottom, towards the side, is sunk throughout its length into a well two inches wide and one and three-quarter inches deep, and is expanded at its end into a circular cavity. This cavity allows of the immersion of the tubes or bells in a moderate depth of mercury without the expense of filling the whole trough being incurred; and the circular end being larger than the other portion of the canal, allows the use of receivers of from two to three inches in diameter.

Fig. 314.

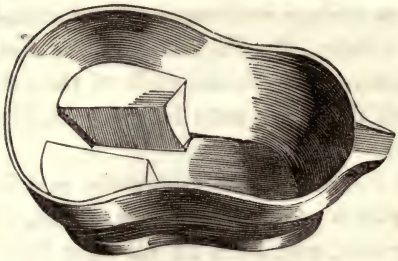


When this cavity is not in use and the mercury required to fill it is needed in the other part of the trough, it is closed with an exactly fitting iron plug which accompanies the vessel for this purpose.

The trough is placed upon the operating-table, and is manipulated with in the same manner as the water trough. For the

convenience of supporting tubes in a vertical position, there is an accompanying clamp with sliding rod, which is attached to the side.

Fig. 315.



The small mercurial trough of porcelain, Figs. 315, 317, very useful in organic analysis, contains usually from ten to twelve pounds, and serves also very conveniently for experiments upon a small scale. Smaller sizes, of about four pounds capacity, are made after the pattern, Fig. 316.

Fig. 316.

Fig. 318 exhibits a cylindrical glass trough, which is used with tubes in organic analysis. It is of glass, fifteen and a half inches high, and is widened at the top. The drawing represents the introduction of lye into a graduated tube by means

Fig. 317.

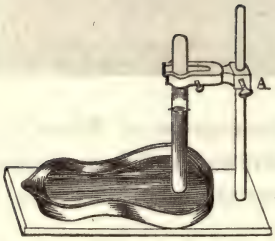


Fig. 318.

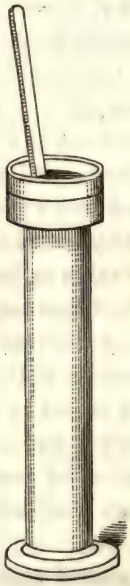


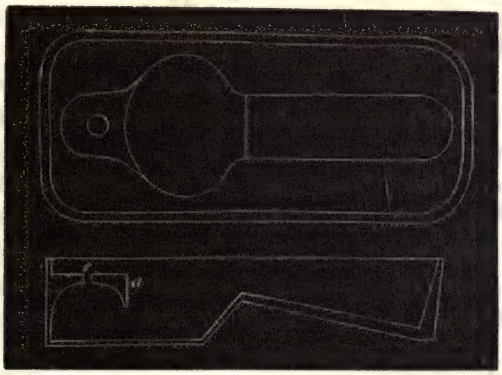
Fig. 319.

of the pipette, Fig. 319, over a column of mercury. The tip of the

pipette is curved so as to facilitate its entrance under the mouth of the tube. This plan is adopted sometimes in lieu of that given at p. 353, for the separation of two gases, by presenting to both a third substance for which either of them has an affinity.

Griffin's trough, which is designed for working with long tubes and the least possible quantity of mercury, has the form of the annexed drawings, the lower one of which presents a sectional view.

Fig. 320.



It has a permanent bee-hive shelf *a a* for supporting tubes in the act of being filled with gas, and a space, which allows liquids to be passed in a small tube, through the mercury, to the gas.

Mercury troughs are generally made of iron, stoneware, or porcelain; but we prefer them of some hard and very smooth wood. The root of the apple-tree fulfils all the requirements; and a carver will fashion a neat, durable, and cleanly trough from a single piece. It is, however, advisable to have the upper part of the sides made of thick glass plate, set firmly in grooves by means of cement. This arrangement permits the level of the metal in the tube to be seen at the lowest points.

In the course of time the mercury of the trough becomes debased by use, either with water, metals, or suspended matters. The water being specifically lighter, may very readily be removed by spreading sheets of bibulous paper on the surface of the mercury, and renewing them as fast as they become saturated. The metals are separable by distillation, the mercury passing over pure into the recipient.

If the impurities are merely coarse suspended particles, as of metallic oxides, straining, by compression with the hands, through a chamois leather bag, will retain them, and even most amalgams, while the mercury passes through the pores entirely or almost pure.

Gases Collected over Air.—Although chlorine can, for temporary purposes, be collected over hot water in which it is not dissolved, that body, as well as iodhydric and bromhydric acids, and certain other gases which are soluble in water, or which attack mercury, are sometimes collected in receivers or bottles filled with air.

If the gas is lighter than air, the end of the disengagement-tube should reach to the upper part of the inverted vessel. As the gas enters, the air is displaced and goes out below, and the jar is known to be full when the gas also escapes. The jar must then be slowly and carefully removed, so that the vacuum left by the withdrawal of the tube, may be completely supplied by the gas simultaneously entering, and its mouth be closed with a plate of ground glass, cork, piece of caoutchouc, or other suitable means.

When the gas is heavier than air, as is the case with chlorine, the disengagement-tube should enter to the bottom of the receiver, the mouth of which should be closely covered with a pasteboard disk. When the gas begins to escape at the mouth, the jar is full, and, after being closed with a ground glass plate or other stopper, carefully removed aside.

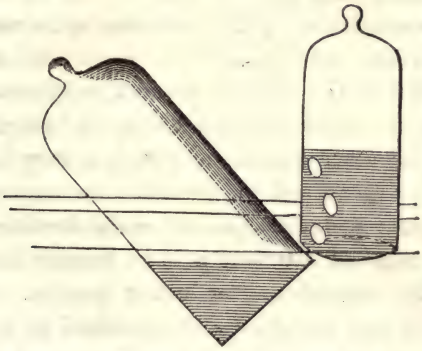
Transfer of Gases.—It is frequently necessary to transfer portions of gas from a large vessel to a smaller one for the purposes of experiment or MEASUREMENT.[1] Having already given

[1] As the volume of gas confined in tubes, or other vessels, over mercury or water varies according to the pressure of the surrounding atmosphere, it becomes necessary in experiments on gases to observe the barometric pressure, or the height of the mercurial column in the barometer, at the time the volume of the gas is observed. Every laboratory ought, therefore, to be provided with a barometer, which should either be a good syphon-barometer or a cistern-barometer, in which the mercury of the cistern may be brought to the same level before observing the height of the column. The latter is generally read off in a scale divided into inches, tenths, and hundreds of inches. As the height of the mercurial column varies according to the temperature, a correction must be made for the temperature of the mercury in the barometer, which, for this purpose, is furnished with a thermometer to be observed at the same time.

the mode of transferring from a gasometer, we will now speak of transvasement over troughs.

If the jar or reservoir of gas is still upon the shelf of the pneumatic trough, the smaller vessel, which is to receive a portion of its contents, is to be entirely immersed in the fluid of the trough, and, whilst full, conveyed bottom downwards to the shelf, and there placed so that it will project over the edge of about a third of its diameter. The reservoir is then brought forward, and the mouths of the two put in connection, as shown in Fig. 321, by

Fig. 321.



inclining the reservoir so that their edges may be in contact:—the gas then passes up in bubbles, and by a little dexterity the rapidity of its flow can be easily regulated.

At pages 126, 202, and 203, we have already given directions for the transfer of gases into tubes and globular vessels.

Bladders are filled from the cocked receivers, Fig. 312, as directed at p. 368. Bladders are cleansed by ablution in weak potash lye, subsequent washings in fresh water and drying. The caoutchouc bags, mentioned at p. 304, are, however, preferable.

When the filled receiver is to be removed from the trough for further essays with gas, it should be gently slid off the shelf into a flat-bottomed plate containing just enough water or mercury to seal the mouth.

Distillation by Steam.—Steam is a most convenient as well as efficient means of distillation in a large number of cases. For example, in the distillation of essential oils, and similar volatile

substances, separable from fixed matter by a heat of 212° to 230° F. The application of the steam must be direct, and provision for its use in this manner has been made at A in our design of the steam series, Fig. 18. The solid matters rest in the body of the vessel upon a perforated lining or diaphragm, and the steam is led into the interior through a pipe ending in a cullender, so as to cause its diffusion throughout the mass. To prevent loss of heat by radiation, the sides of the containing vessel should be wrapped in woollen. As the volatile substance is eliminated from its fixed associates, it becomes involved with the arising steam, and passes over into the condenser, and ultimately into the receiver, where the two form distinct layers according to their differing densities; and the water, or condensed steam, may be thus separated from the valuable product, as directed at p. 340.

By passing the steam through hot tubes before its admission into the still or other containing vessel, it may be superheated to a very high degree, and in this state becomes a powerful decomposing agent; and consequently useful for those distillations in which the required distillate is to be formed from the decomposition of the original matter under process. The matters treated in this way are generally contained in metallic vessels and tubes capable of resisting a certain amount of pressure. The superheated steam is led directly into and through them; so that the distillate becomes incorporated with the aqueous vapors, and passes out with the latter into the condenser and receiver.

Distillation in Vacuo.—This kind of distillation is resorted to for the production or purification of many volatile matters which are alterable in the air or in aqueous vapor. Retorts drawn out at their beak into a very narrow opening, or glass tubes, fashioned over the blowpipe flame to suit the process, are the vessels commonly employed. After the vessel is charged, heat is applied to the bulb portion, and as soon as it becomes filled with vapor and all air is expelled, the tube should be heated over a lamp. After the annealing of the closed end, it, being intended for the reception of the distillate, should be exposed to the influence of cold while the process is being conducted. If the retort is used, the receiver with which it is connected must be warmed over the sand-bath, and in delicate experiments exhausted by means of the syringe, Fig. 99, or air-pump, Fig. 47.

Dry or Destructive Distillation.—This kind of distillation has a more general application to solids than liquids; but, in either case, the substances under treatment are highly heated, in *close* vessels, until decomposition ensues, for the sake of the products thus generated. These products are mostly the distillate, which is either gaseous or liquid, or both simultaneously; but in rare instances, the residuum in the retort is the desirable matter. The operation is practised for the decomposition of certain kinds of bodies, particularly those of organic nature. The new compounds are formed by an interchange of the ultimate components of the original body under the influence of heat. The process for organic analysis is a veritable destructive distillation, and has already been described at p. 247. The tubes for this and similar experiments being long, require the use of the gas furnace, Fig. 166, for heating them. The product in that case being gaseous, is either absorbed by a suitable liquid, as shown by Fig. 139, or received over mercury, as seen in the annexed drawing.

Fig. 322.

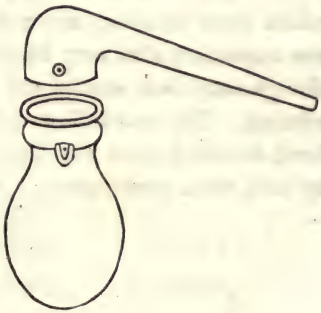
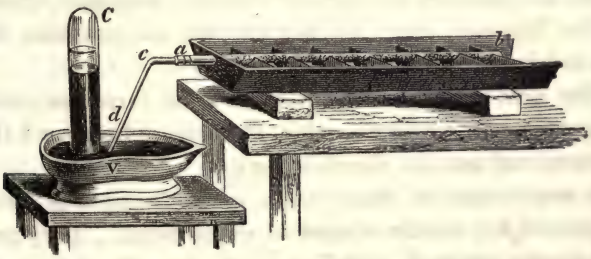


Fig. 323.

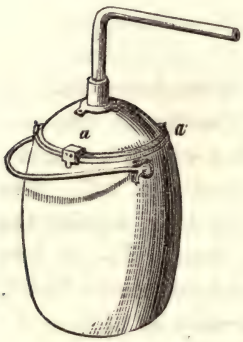


When the distillate is both gaseous and liquid at the same time, the generating apparatus must have two receiving vessels connected with it, one adapted to the absorption of the gas, and the other for the condensation of the liquid.

The vessels in which dry distillation is performed are mostly

of iron, and occasionally of porcelain and earthenware; but, in either case, the covers must be movable for convenience of removing the residuum, which, being very often dry and hard, adheres to the bottom of the retort with great tenacity. Earthenware and porcelain retorts are only used in very exact experiments, for which those of metal are not well adapted. Those of porcelain are expensive and very fragile; while the earthenware retorts, though much less costly, are only less apt to crack during the heating. The usual form is seen at Fig. 322, which shows the head detached from the body. The two are cemented together by lute, when under process, so as to form a steam-tight joint.

Fig. 324.



Iron retorts have already been described at p. 332, and another form is now presented in Fig. 324, which shows one with its head fitted to the body by ground joints, and held securely in place by a clamp and screw.

As examples of the effect of dry distillation upon certain substances, citric acid may be converted by it into carbonic acid and oxide, acetone, aconitic acid, and water; fatty bodies modified into new substances; and resins transformed into oily liquids and gaseous carbohydrogens.

In the dry distillation of nitrogenized bodies, the resultant products are complex, and contain nitrogen, ammonia, cyanogen, &c. For instance, indigo yields carbonate and prussiate of ammonia and kyanole.

In the arts, the dry distillation of wood furnishes charcoal, pyroligneous acid, pyroxylic spirit, creasote and tar; and that of bituminous coal and fat, illuminating gas.

The employment of close vessels in distillations is becoming very general for certain classes of experiments. They present the great advantage of excluding the air from the interior; and afford the means of exciting reaction in substances which would otherwise vaporize, and escape under atmospheric pressure. Moreover, the internal pressure thus created, is a condition which favors the action of the heat in augmenting the affinities

of the elements of the substance under process of destructive distillation.

Berthelot's suggestions (*Journ. Pharm. et Chim.* XXIII), in regard to the proper mode of managing close vessels, in heating operations, are so full of serviceable instruction, that we annex an abstract.

For temperatures below 212° F., the containing vessels may be heated by water-bath, which should be covered to prevent the spattering of the boiling water. For 212° F. to 750° F., the heating medium must be an oil-bath in a close vessel, the necessary precautions being observed to prevent explosions by the ignition of the boiling oil or its vapor. To this end the boiler should not be filled to more than half its depth with oil, and should rest by a flange upon its circumference, and midway from the bottom upon the top of a strong and close chamber, surmounting a furnace, the fire-hole of which must have its entrance upon the outside of the apartment. The fire-grate should be about 23 inches from the bottom of the boiler. The boiler itself should be about 2½ feet in height and slightly conical, and should be enveloped with a brickwork casing, so as to shut off all communication between it and the fire, except by means of the furnace part. To indicate the temperature of the oil, a long thermometer is adjusted in a hole in the top. For heating, glass tubes should be confined in iron tubes, closed at one end by hammering, and at the other with a screw plug; this arrangement prevents the spattering of the oil in the event of the glass tube breaking, though in some rare cases, as in the heating of alcohol to 750°, the explosion of the glass tube is so violent as even to break the iron envelop, and the inflammable gases thus projected through the heated oil are liable to take fire. When such a contingency is to be apprehended, the iron tube should also be enveloped in a tight sheet-iron muff, for the purpose of confining the inflammable gases in case of accident. The whole is then immersed perpendicularly in the bath, so that its entire length may be covered during the heating. The oil for the bath should be prepared by boiling it in the open air until it has acquired an almost solid consistence when cold. In this state it can be heated to above 680° without sensible ebullition. After having been used continuously for

several days, the oil is then able to bear from 750° to 850° without boiling, and will resist decomposition up to a dull red heat.

Experience is the best guide for the regulation of the temperature of the bath; but care must be taken not to allow any sensible variation. The contents of the containing vessels acquire the temperature of the bath in an hour, provided the latter has been kept, all the time, at a fixed temperature.

For heating to redness, Liebig's furnace, Fig. 139, or Hoffman's furnace, Fig. 166, must be used; but it will be necessary to place the tubes in the centre of a larger sheet-iron tube, so as to intercept the contact of the flame with the glass. When glass flasks are used as the containing vessels they should be sealed by closing the mouth over a blast lamp; but as these vessels are not capable of resisting a pressure of more than three or four atmospheres, tubes are preferable, and almost exclusively used. The glass material of which they are made should be very refractory, free from lead, and insensible to the action of chemical agents. That kind of tube used for organic analyses will be very suitable, provided it is sufficiently thick. The thickest resist the tension of water (steam) up to 520°, and that of spirits of turpentine as high as 680° F.; or, in other words, they will stand a pressure of 50 to 60 atmospheres.

When extreme temperatures are required, it is not necessary to resort to tubes of other and more resistant material than glass, for those of the latter can be made available by proper management. To this end, the substances to be acted upon are inclosed in a tube of about four-tenths of an inch in diameter, which, in its turn, is placed in an outer tube containing a liquid less volatile than those in the inner tube, and of such a nature as will not cause the explosion of the enveloping tube, but only counteract, by its tension, a part of the internal pressure of the inner tube. Alcohol and ether may be thus heated to 680° by using essence of turpentine as the liquid in the exterior tube.

In preparing the tube, the end should be closed in the flame without the use of a blowpipe; and subsequently annealed. After cooling, the solid reagent, if such is to be used, must then be introduced, and the other end carefully drawn out to a point. Great care must be taken in this manipulation to preserve, in the different parts of the tube, the original proportion of internal diameter and

thickness; for it is especially upon this mutual ratio, and not upon the absolute thickness, that the power of resistance depends. When the tube is cool, the liquids are then introduced, and the point sealed in the flame of the lamp. The point of closure must be very fine, as in the disengagement of gases it allows the opening of tubes without explosion.

If the action of the air is to be avoided, before sealing the tube, the latter must receive an atmosphere of carbonic acid or hydrogen, and this is furnished from a generator, Fig. 172, the delivery-tube of which connects with its point. After letting in a continuous current for 8 or 10 minutes, the operation is completed.

The quantity of liquid to be introduced into the tube varies with the degree of heat to which it is to be carried; they may be filled to two-thirds their capacity with liquids which are to be heated from 650° to 750°. In all cases they are set perpendicularly in the bath, and so as to be entirely covered by the oil.

Tubes which are to be heated to redness must have a length of 20 to 24 inches; and the charge of liquid introduced into them may be 1 to 1½ per cent. of their capacity. When gases are to be subjected to treatment, the tube is drawn out, so as to present a very slender neck, with a funnel-shaped mouth, filled over mercury, and dexterously sealed at the neck by drawing off the funnel-mouth over the lamp.

When the tube has been sufficiently heated, it is to be taken from the bath and opened, but as it may contain gases in such a quantity and under such a pressure as may produce explosion upon the least shock, great care is necessary to prevent accidents.

If the generation of a permanent gas, during the reaction, is anticipated, the tube must be inclosed in several successive envelops of sheet-iron, and so secured at both ends that only the tip of the drawn-out end shall project. After the heating, and when the bath is cooled completely, the screw-nut is removed from the iron tube, and the latter slightly inclined, so as to allow the glass tube to fall out gently upon a cloth.

If it is not desired to study the gaseous products of the operation, the tube is then wrapped around with three or four folds of the towel, so as to leave only the point projecting, which is then clipped off with a pair of pincers. If the effervescence

produced by the disengaged gas is excessive, and causes loss of liquid, then the lower end may be broken over a beaker glass.

In certain cases, it is necessary that this manipulation should be practised at a little distance to avoid personal injury; for example, in heating to redness tubes containing one-fifth their volume of hydrochloric ether in contact with hydriodate of ammonia, the resulting gases are sometimes so abundant that it is impossible to open the tube without explosion, and in such case, if the solid products are the only ones required, then the tube may be wrapped completely up in a cloth and thrown on the floor. The solid bodies will be found in the cloth mixed with the fragments of glass.

If the gases are the required products, then the tube must be quickly passed up into an inverted receiver or tube, filled with mercury, and its point broken against the interior of the top. The receiver should be held at an inclination of thirty degrees, and in such a manner as to protect the person in case of explosion. For greater safety, it is advisable to envelop the receiver in a sheet-iron casing.

The disengaged gases should be studied immediately, as they may, in some instances, undergo rapid changes over mercury, by the loss of one or more of their components. As an instance, Berthelot observes, that a mixture of hydrogen and carbonic acid lost all of the hydrogen, even with two intervening fluid strata, one of spirits of turpentine of four-tenths of an inch thickness, and the other of mercury fifteen times as deep.

CHAPTER XVIII.

LUTES.

In all combinations of two or more pieces of apparatus or parts of them, there is a necessity, in chemical operations generally, of some means of hermetically closing the interstices of their joints so as to protect the inclosure from all outward communication. This is particularly requisite in SUBLIMATION, DISTILLATION, and other heating operations, and indeed in all expe-

riments with gases and liquids, wherever it is desired to confine the volatilized particles within the vessels and to prevent their escape into the atmosphere and consequent loss.

To accomplish these ends we make use of lutes, which must vary in composition and mode of application with the material and construction of the apparatus, the temperature at which it is to be heated, and the nature of the generated products.

Caoutchouc.—This substance, in sheets, is particularly useful for forming flexible tubes by which joints may not only be rendered hermetical but also flexible. For delicate apparatus it is particularly applicable even at high temperatures. The tubes are made as directed at p. 304, and tied above and below the joint as at *x*, Fig. 218. Sometimes india-rubber is replaced by muslin, payed over after its adjustment around the joints with a paste made by the mixture of caoutchouc and spirits of turpentine.

Bladder.—Bladder well cleansed and divided into strips answers very well to a limited extent. For example, when moistened and coated with white of egg or solution of bone-glue or of isinglass, it forms an excellent covering for the joints of retorts, tubes, and the like, to the surfaces of which it adheres tenaciously. When, however, the contained ingredients generate corrosive vapors, and so rapidly as to strain the apparatus, the bladder is unserviceable.

Flaxseed Lute.—Flaxseed meal mixed to the consistence of a paste with water, milk, lime-water, or starch paste. This lute is very manageable and impermeable, but does not withstand a heat greater than about 500°.

If just the sufficient quantity of water be added to quicklime to reduce it to a dry powder, and the two mixed well and rapidly with white of egg diluted with its own volume of water, and the mixture spread immediately upon strips of linen and applied to the part, which is then sprinkled with quicklime, a good cement is made. Instead of white of egg, lime and cheese may be used, or lime with weak glue-water or blood. This lute dries very rapidly, becoming very hard, and adhering strongly to the glass, but its great inconvenience is the want of flexibility.

In spirituous distillations, the joints of the apparatus may be closed very readily and effectually by a stiff paste of equal

weights of whiting and flaxseed meal, mixed with water. We have found this lute invaluable notwithstanding its want of flexibility. It is the most easily made and most cleanly of all lutes, and when the pressure of the contained vapor is considerable, it can be covered with strips of bladder soaked in solution of bone-glue, which will prevent all leakage.

Lime and Bone-Glue.—Freshly slacked lime made into a thick paste with a strong solution of bone-glue, makes an adhesive lute very applicable for closing the joints of vessels which are to be subjected to high heats; as, for example, those in which the distillation of lime and sal ammoniac is conducted for the production of gaseous ammonia.

Plaster of Paris.—Calcined gypsum made into a paste with glue or starch water, answers the same purposes as the above. When covered with strips of bladder it is rendered entirely impermeable by gases. A coating of oil or of a mixture of oil and wax has the same effect as the bladder, and the lute will then stand a dull red heat.

Plastic lute is made by dissolving melted caoutchouc in hot linseed oil, adding finely powdered pipe-clay and kneading the whole together into a homogeneous mass. The longer it is kneaded the better is its quality, and to prevent its hardening the caoutchouc should not be in deficient proportion. If it should become hard by keeping, it may be softened by kneading with a little spirits of turpentine.

This lute closes the joints without hardening, and can be removed at any time during the operation, to allow a change in the position of the parts of the apparatus.

For the distillation of acids or other corrosive vapors, it is very applicable.

Soft cement is prepared by fusing yellow wax with half its weight of crude turpentine and a little Venetian red, in order to color it. It is very flexible, and takes any desired form under the pressure of the fingers. It is extremely useful at common temperatures for tightening tubes in cork, and as a coating for rendering corks impermeable to gases.

Resinous, or hard cement, is made by fusing together at the lowest possible temperature, 1 part of yellow wax and 5 or 6 of resin, and then adding gradually 1 part of red ochre, or finely

powdered brickdust (plaster of Paris succeeds very well), and then raising the temperature to 212° at least, until no more froth arises, or agitation takes place, and stirring it continually until cold. This cement is employed in a hot state, and is very much used for fixing brass caps, &c., to air-jars, and as an impermeable coating for the interior of wooden vessels.

Lute for joining Glass and Steel.—A saturated solution of mastic in alcohol, mixed with a solution of isinglass in dilute spirits, to which is added a small portion of galbanum or ammoniac, is an excellent cement for joining glass to glass, or glass to steel. The mixture must be kept in a well-stopped bottle, and be always warmed previous to use.

Lute for joining Crucibles.—A mixture of fine clay and ground bricks kneaded into a paste with water, holding in solution one-tenth of borax, answers admirably for luting the joints of superposed crucibles. An excellent lute for this purpose and also for metallic subliming vessels, is finely powdered Stourbridge clay, containing a little *sal enixum*, and made into a stiff paste with water.

Iron Cement.—This mixture is used for making permanent joints generally between surfaces of iron. Clean iron borings or turnings are to be slightly pounded so as to be broken, but not pulverized; the result is to be sifted coarsely, mixed with powdered sal ammoniac and sulphur, and enough water to moisten the whole slightly. The proportions are, 1 sulphur, 2 sal ammoniac, and 80 iron. No more should be mixed than can be used at one time.

Fire Lute.—The best fire lute is that employed by Mr. Parker, and is composed of good clay 2 parts, sharp washed sand 8 parts, horse-dung 1 part. These materials are to be intimately mixed; and afterwards the whole is to be thoroughly tempered, like mortar. Mr. Watt's fire lute is an excellent one, but is more expensive. It is made of finely powdered Cornish (porcelain) clay, mixed to the consistence of thick paint, with a solution of borax, in the proportion of two ounces of borax to a pint of hot water.

Fat lute is prepared by mixing dry clay, in a fine powder, with drying oil, so that the mixture may form a ductile paste. It should be kept under cover, preferably in a greased bladder.

When this paste is used, the part to which it is applied ought to be very clean and dry, otherwise it will not adhere. This lute is adhesive, and stands a pretty high heat, but requires to be fastened down with strips of bladder. Its greatest disadvantage is the difficulty of stopping holes which may be blown through it by escaping vapor.

Lead and Oil Lute.—Red lead mixed with boiled linseed oil is excellent for sealing the joints of steam-vessels. It hardens readily and bears a high heat.

Lute for coating Fire Vessels.—Faraday gives the following directions for luting iron, glass, or earthenware retorts, tubes, &c., for furnace operations. When the lute has to withstand a very high temperature, it should consist of the best Stourbridge clay, which is to be made into a paste, varying in thickness according to the judgment of the operator. The paste should be beaten until it is perfectly ductile and uniform, and a portion should then be flattened out into a cake of the required thickness, and of such a size as shall be most manageable with the vessel to be coated. If the vessel be a retort or flask, it should be placed in the middle of the cake, and the edges of the latter raised on all sides, and gradually moulded and applied to the glass; if it be a tube, it should be laid on one edge of the plate, and then applied by rolling the tube forward. In all cases, the surface to be coated should be rubbed over with a piece of the lute dipped in water, for the purpose of slightly moistening and leaving a little of the earth upon it; if any part of the surface becomes dry before the lute is applied, it should be re-moistened. The lute should be pressed and rubbed down upon the glass, successively from the part where the contact was first made to the edges, until all air bubbles are excluded, and an intimate adhesion effected. When one cake of lute has been applied, and is not large enough to cover the whole required surface, another must be adapted in a similar manner. Great care must be taken in joining the edges, for which purpose it is better to make them thin by pressure, and also somewhat irregular in form, and if at all dry, they should be moistened with a little soft lute. The general thickness may be about one-quarter to one-third of an inch.

Being thus luted, the vessels are afterwards to be placed in a warm situation, over the sand-bath or near the ash-pit, or in

the sun's rays. They should not be allowed to dry rapidly or irregularly, and should be moved now and then to change their positions.

To prevent cracking during desiccation, and the consequent separation of the coat from the vessel, some chemists recommend the introduction of fibrous substances into the lute, so as mechanically to increase the tenacity of its parts. Horse-dung, chopped hay and straw, horse and cow hair, and tow cut short, are amongst the number. When they are used, they should be added in small quantity, and it is generally necessary to add more water than with simple lute, and employ more labor to insure a uniform mixture. It is best to mix the chopped material with the clay before the water is put to it, and upon adding the latter, to effect the mixture, at first by stirring up the mass lightly with a pointed stick or fork; it will then be found easy, by a little management, to obtain a good mixture without making it very moist.

The luting ought to be made as dry as possible, consistent with facility in working it. The more wet it is, the more liable to crack in drying, and *vice versâ*.

Mr. Willis recommends, when earthenware retorts, &c., are to be rendered impervious to air, the following coating. One ounce of borax is to be dissolved in half a pint of boiling water, and as much slacked lime added as will make a thin paste. This composition is to be spread over the vessel with a brush, and when dry, a coating of slacked lime and linseed oil is to be applied. This will dry sufficiently in a day or two, and is then fit for use.

Cement for Labels.—Gum tragacanth boiled with hot water makes the most adhesive paste for securing labels upon glass or other smooth surfaces. The addition of a few drops of acetic acid retards its decomposition and keeps it unaltered for a long time. By moistening the labels with a very weak alcoholic solution of corrosive sublimate, before pasting them on the bottles, they are rendered proof against the obliterating action of mould and dampness.

Mode of applying Lutes.—Lutes are applied whilst soft, being adjusted to the joints by the hand. As they become dry, occasional compression by the fingers is necessary to render them compact. So also when any leaks occur they must be closed

with fresh portions of lute smeared over and pressed in by the end of the thumb. When bladder or muslin is to be pasted over lute, the joint made with the latter must first have dried.

When the operation is finished, and the apparatus is to be disconnected, the lute must be removed first with the hands. If, as is often the case in the use of hard lutes in fire processes, they adhere tenaciously, then the use of a knife, or when the vessels are metallic, a chisel becomes necessary.

CHAPTER XIX.

THE BAROMETER.

The Barometer, so important in its discovery as marking a great epoch in the history of science, has not become less so in its subsequent varied applications as an indispensable instrument for physical research. Not to speak here of its use in meteorology for indicating the changes that are occurring, periodically or irregularly, in the weight of our atmosphere, or of its employment in geography for determining expeditiously and with reasonable accuracy differences of level between different points of the earth's surface, the demand for its appliance in the laboratory is almost ceaseless. Not a weighing can be made, at least where the aim is minute precision, of solid bodies, without its observation, unless (what is rarely the case) the object to be weighed and the weights themselves are of the same material, or have the same specific gravity; while in the measurement of gaseous bodies, whose volume, at any moment, evidently is regulated by the pressure of the atmospheric medium which circumscribes them, its readings have to be continually combined with whatever other observations that have been made, in order to educe the proper arithmetical result.

With such frequency of necessary and varied appliance, there might be expected (as is in fact realized) a corresponding variety in the arrangements, both formal and substantial, of the instrument itself; all subject, however, to one essential condition, viz., the establishment and maintenance of a perfect vacuum in some part of the apparatus. Besides this indispensable condition there

are others, too, of greater or less generality, which have also to be considered; such as the precision with which the zero of the scale can be ascertained, the permanence of such zero, the sympathy between the scale itself and the material movement in the apparatus which it is intended to measure, the openness of said scale, or the minuteness with which its readings can be made, &c. There will be occasion to indicate these conditions more expressly in the account, which is of sufficient interest to be given here, briefly, of the main modifications which the instrument has successively and at divers times undergone.

All these modifications may, for convenience in description, be grouped into two divisions consisting, 1st, of Stationary Barometers; and, 2d, of Barometers which are intended to be portable. These last, because of the geographical use which stimulated their device, are ordinarily termed *mountain*-barometers; and by the former are meant such as not being devised for transportation require a special caution in being moved from place to place, and a treatment afterwards more or less equivalent to the pains which were requisite in their being first set up. In other respects, as, for instance, in regard to the conditions which have been just spoken of, there is no generic difference between them, only that while the mountain-barometers can fulfil at all times the functions of the stationary ones, the converse does not hold good. Hence, except for purposes of ornament or amusement, and for aims which may be called extra-technical, stationary barometers are now rarely constructed. But whenever or however constructed, they consist essentially of a glass tube, closed at one end, set vertically, with the closed end uppermost, and containing some fluid mercury, sulphuric acid, water, &c., the height of the column of which will be, of course, inversely as its specific gravity, in order to be in equilibrium with the pressure of the atmosphere; and their distinctive characteristic is the permanent aperture of the lower end of the tube, and the direct contact of the fluid column there with the external air.

Of this class the wheel-barometer may serve as a type.

Wheel-Barometer.—This is the instrument most generally procured when the object is to have an amusing weather-glass; and its construction can be readily understood from the adjoining sketch, Fig. 325, in which the dotted lines show the tube turned

up into a short syphon, through whose permanent aperture a float enters and rests on the mercury surface, counterpoised so as to yield to or follow that surface, by a weight the connecting-string of which passes over a pulley, as seen also in dotted lines. The arbor of this pulley passes horizontally to the outside of the casing, and there is fitted with an index as shown, which index revolves to the left hand or to the right, according as the surface of the mercury in the syphon rises or falls, and points out on the graduated circle around it the proportionate extent of such rise or fall. As the aggregate weight of the float and counterpoise is very small, and might not create friction enough to prevent the string connecting them from slipping on the pulley, it is usual to sever said string, and attach its ends to the pulley, which is turned with a double groove. The diameter of this pulley is most conveniently made such that a half revolution shall correspond to the range that is exhibited on the dial. When the range takes in the whole circumference of the dial-plate, of course a whole revolution of the pulley becomes necessary, and the string is better unsevered. It is plain that in this arrangement of two columns, the vertical movement of either is but half of what it would be in a single one; and in so far the scale, were it a vertical one, would be only half as serviceable; but this can be counteracted to any extent, and is so in a greatly multiplied proportion by the reading being circumferential. Wheel-work is sometimes attached to the pulley-arbor, by which minute readings can be made still more sensible.

Fig. 325.

But, with all this, the friction of the apparatus, and the difficulty of boiling the mercury in the tube, without which ebullition, the freedom of the column from air and the perfection of the vacuum above can never be obtained, have consigned this form to uses where accuracy is not aimed at, and for a laboratory implement it is altogether unsuitable.

Barometers of the other kind, whose unsealed extremity yet admits of being cut off at discretion from connection with the ex-

ternal air, may be divided into two classes, viz., *cistern* and *syphon* barometers. In the first, the original single tube, which with Toricelli or Pascal plunged its open extremity into a wide cup or bowl of quicksilver, has its own cup or cistern permanently attached to it, protected from fracture by suitable precautions to support and strengthen it.

Newman's Barometer.—In some kinds, as in the barometer of Newman, the cistern is made of iron, and the passage for air, from the outside to the inside, is effected by means of a screw-plug, which is removable at pleasure. When this is open, the pressure maintains the mercurial column at a corresponding height, which is read off with the aid of a vernier from the enclosing brass tube; if this pressure increases the column rises; if it diminishes the column falls. In either case, it is clear that the displacements in the tube correspond to inversely proportionate displacements in the cistern, by which the level of the fluid there is raised or depressed; by which it differs from what was assumed in the laying off of the scale as its starting-point or normal-zero, and by which there is, to the extent of difference in question, an error in the apparent height of the column. As this normal-zero mark, as well as the mercury surface in the cistern, are no longer visible after the instrument has been put together, the correction of this error has to be found in a previous comparison made by the maker, and furnished with or recorded on the instrument, of the relative capacities of the tube and of the cistern. If the tube and cistern were alike perfectly cylindrical, it would be sufficient for ascertaining this correction to know their diameters respectively, to the squares of which the displacements would be inversely proportionate. Thus, if the tube was 0·25 inch bore, and the cistern 2·5 inches diameter, or 10 times as great, then a fall of 1 inch in the tube would be compensated by a rise of 0·01 inch in the cistern, or, in general, the rise in the cistern would be $\frac{1}{100}$ of the fall in the tube, and *vice versâ*. But, as this regularity of shape is rarely or never existing, the usual mode is to fill the entire tube, or a known length of it, with mercury, and then extravasating it into the cistern, to measure the difference of level which has been produced by the addition. So, if 30 inches length of tube is found to contain a quantity of mercury enough to raise, when poured into the cistern, the previous sur-

face by 0·3 inches, the technical correction for *capacity of cistern* is $\frac{1}{100}$ (as before) of the difference between any actual reading and the reading of the column originally, when, in the construction of the instrument, the zero of the scale was adjusted to the surface of the mercury in the cistern. This last-named reading is by artists called the *neutral point*, and is stated along with the correction for capacity. It follows from the very epithet *neutral*, as well as from what has been said just now, that the application of the capacity-correction, *i. e.* whether additively or subtractively, depends upon which side of the neutral point the surface in the cistern, at the epoch of the actual reading, may happen to be, *i. e.* whether above or below. If the actual reading is greater than that for the neutral point, then the cistern-surface must be below said point, and the correction for capacity is additive, and *vice versâ.*

Thus, for example, the correction for cistern-capacity in a given case was $\frac{1}{41}$, and the stand of the neutral point was 30·180 inches. Upon one occasion the reading of the column was found to be 30·526 inches. Of course, the ascent in the tube had been (30·526 — 30·180 =) 0·346 inch; and the corresponding depression in the cistern had become $(\frac{0{\cdot}346}{41} =)$ 0·008 inch, which, because of its sign, is additive, and, therefore (30·526 + 0·008 =) 30·534 is the reading that would have been shown, if, by any contrivance, the cistern-surface could have been maintained at the zero of the scale. So, again, with the same barometer occurred an apparent stand of 29·742 inches, showing a descent in the tube of (29·742 — 30·180 =) — 0·438, and a corresponding rise in the cistern of $\frac{-0{\cdot}438}{41} = -$ 0·011 inch, which, because of its sign, is subtractive, and the true reading would have been (29·742 — 0·011 =) 29·731 inches, could the zero have remained as at first.

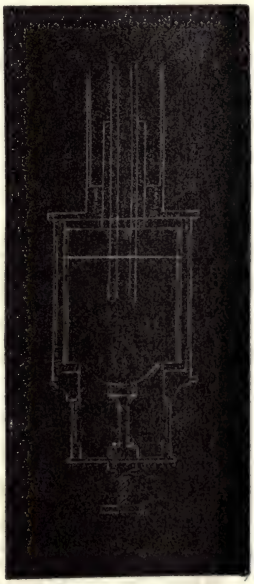
The cumbrousness of this correction, and the possibility of error from confusing the signs, and adding where one ought to subtract, or *vice versâ*, stimulated devices for maintaining the zero so as to dispense with the necessity of any correction. The readiest suggestion was to make the bottom of the cistern movable, so as to be able always to restore the surface there to the

original zero from which the graduation started. Of course, the surface in the tube would, in such case, undergo an equable displacement, and there the apparent reading became normal and true.

One of the modes of effecting this is that proposed and executed by Mr. Troughton some seventy years since, and, in fact, preceding by nearly half that period the iron cisterned barometers of Newman, which have been just now spoken of. The details of Troughton's arrangement will be easily understood from the adjoining sketch; and they have so far approved themselves in practice as to be substantially and with but slight variations in form perpetuated to the present day in England and America.

Troughton's Barometer.—The sketch of this instrument, Fig. 326, is restricted to the lower part of the apparatus, and is intended to show within a glass cylinder, of about 2·5 inches in diameter, and as much in height, whose bottom of buckskin, cemented on to the rim, and still farther supported there by a brass ring that is screwed up tight by the outer brass casing, enables it to hold the mercury. The top is of wood or iron, also leathered, through which the tube plunges into the mercury; and appropriate shoulder-pieces serve both to steady the tube and to receive and bear the outside brass cylinder that encompasses and protects the tube. The cistern thus furnished is enclosed in a brass cylinder, in the base of which works vertically a screw terminated above in a suitable disk, that holds and can be made to press against the leather bottom, and thus enlarge or diminish the capacity of the cistern. This outside brass cistern cover is not everywhere continuous; but about one-fifth of the height from the top has two opposite horizontal slits cut in it about 0·25 inch wide, thus allowing one to see through the glass the surface of the mercury, and the stem of the tube when the screw is lowered. The upper edge of these slits is the

Fig. 326.



zero of the graduation and the normal level of the surface in the cistern; and to this edge, the eye being applied at the same level and receiving the light through from the opposite side, the surface of the mercury is lifted by working the screw until the line of light thus received becomes the least possible, or until the slightest further turn of the screw would shut it out entirely. This phenomenon of the *minimum visibile*, or the least line of light, is the test of the zero also equally when the mechanical adjustments happen to be made in the contrary direction, and the screw to be lowered instead of raised.

As to the upper part of the Troughton barometer, it may be said that the glass tube is sheltered by a brass one rather larger than itself; which brass tube is continuous for about half the height, and for the remainder is slotted on both sides opposite, so as to expose to view the mercurial column and the tube to near its very top. On one edge of one of these slots the graduation is made, its zero being the edge of the slit in the cistern beforementioned, its actual division commencing at about 15 inches, being continued generally up to 31 inches, and its subdivisions capable of being read to $\frac{1}{500}$ or sometimes $\frac{1}{1000}$ of an inch, by means of a vernier, which is inscribed on a smaller brass tube that moves inside of the slotted one, and is so rebutted as to present the vernier always to the graduation. The motion of this sliding-tube, through spaces of one-tenth of an inch and upwards, is by hand; its smaller motions are regulated by a screw which works vertically downwards in the very top of the brass casing, and by means of which the lower edge of the sliding-tube can be brought into optical contact with the meniscus or upper convex surface of the mercury in the tube. This contact is effected in the same way as that practised for the adjustment of zero, viz., the screwing down until the line of light between the mercury-surface, which coincides with the beginning of the vernier and the sliding-edge, is the least possible.

When the instrument is intended to be transported from place to place, the function of the lower screw is then to force the column up to the top of the tube, which is ordinarily visible, or rather in order to avoid all strain and consequent fracture very near to the top. The sharp click that is made when after such screwing

up is done, the instrument is reversed, and the cistern held uppermost, is evidence that the column is not unduly pressed.

This method of reading by an adjustable surface from a permanent and visible zero, has, from its facility and real merit, obtained wide acceptation; and many instruments are made which have this feature, though very few other of the Troughton arrangement. In those, the cistern is ordinarily made of wood into the long slits or windows, in whose sides narrow pieces of glass are cemented to allow the transmission of light; the bottom is of leather as before; the screw works in the same manner; the zero of the scale is defined by the edges of the slit in the enclosing brass case similarly. But the case to protect the tube is wood; and the scale is a flat slip of brass fastened against the jamb, which is produced by cutting away, for a height of twelve or fifteen inches from the top, about the third part of the matter of the wooden cylinder, so as to show the tube on one side. The reading is made by a vernier slide, worked by hand upon the slip aforesaid, and having a curved lateral index that embraces a part of the tube, and may be adjusted to the meniscus of the column. Tube, and slide, and hollow, are all covered, when desirable, by a portion of brass tubing,—nearly a semicircle in section,—which works round horizontally, and screens, or at pleasure reveals, what is within. These barometers are hung by a ring at the top of the wooden case to some convenient support; while, in the Troughton arrangement, the suspension is by a collar and trunnions, placed about midway of the length, and resting in gimbals that are set in the head of the tripod, which, when the instrument is dismounted and reversed, serves for its packing-case.

This method of adjustment to zero, however, has not been so favorably received by the Continental artists, who prefer the mode adopted by Fortin. In this the glass cistern is much more revealed than in the Troughton arrangement, in order to have illumination enough to see the mercury-surface, and also an ivory point which projects vertically downwards from the top of the cistern. Otherwise, the arrangements are similar to what has been described; the bag is screwed up, and the cistern surface displaced, until the direct image of the ivory pointer and its image reflected from the mercury-surface just meet apex to

apex. When this optical contact is made, the ivory point, whose very terminus is in the plane of the zero of the graduation, just touches without piercing the mercury-surface, and the scale is properly adjusted to be read.

Hassler's Barometer.—Mr. Hassler devised, some twenty years ago, for use in the United States Coast Survey, something quite different from all the types that have been indicated. In this, the principal parts, the tube and the scale, are no longer attached but separated, and the cistern, which may be any convenient vessel that will hold mercury, is also separate, and may be applied, during cessation of its functions here, to various other uses or purposes to which it may be fitted or convertible. The adjoining sketch of the suspensory and upper part of the apparatus, Fig. 327, will render the following brief description sufficiently intelligible. The tube there is a naked tube containing mercury. At its upper end, a metallic ferrule embraces it, with a curved piece of wire fastened to its basket handlewise, and allowing it to be suspended on a hook. To the lower end of the tube is cemented a steel ferrule, with two projecting prongs or arms diametrically opposite, over which slips, through guide-holes, a steel plate having a leather cushion on one side of the diameter to fit the end of the tube. When this plate is pushed down, two slots in the arms allow a key or wedge to be slipped through, the pressure of which forces the plate and cushion sufficiently home to retain the mercury. This plate is so pushed home and keyed when the tube is prepared for transportation; when it is set up for observation, of course, the key is taken out, and the plate removed. The scale is a curved slip of brass, ordinarily divided from 25 to 31 inches, and with a vernier that reads down to $\frac{1}{100}$ of an inch, properly fastened to a light steel rod, whose lower end is the zero of the graduation, and is

Fig. 327.

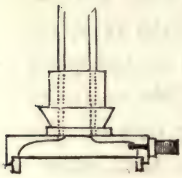
intended to be in contact with the cistern surface. The upper end of the rod is tapped with a screw, which is intended to pass through an oblong hole in a bracket, as seen in the sketch, and to be retained on the other side by a nut. Another similar hole in the same bracket is for a hook to support the barometer-tube, which hook is likewise held and its motion regulated by a nut above. The rectangularity of the hole, which corresponds to a flattening of the sides of the screw, is intended to prevent the turning of the whole apparatus when the nut is worked. At the zero end of the steel rod, and at some prescribed distance above the very zero (in fact, 0·5 inch), a mark is found going round the rod; to which mark it is intended, by working the nut before spoken of, to adjust the fiducial edge of an ivory float (of exactly the same height from its base to said fiducial edge as the prescribed distance aforesaid), so that when the edge and the mark correspond, the base of the float and the end of the rod are exactly on the same level, both in contact with the mercury-surface, and said surface, therefore, at the zero of the scale.

In the use of this form of instrument, supposing it just taken out of its packing-case, and with the open end outwards, the first thing is to withdraw the key that holds the plate; then to remove the plate; then to pour a little clear mercury from the vessel used as the cistern (and which is assumed as having been previously filled from the travelling flask or otherwise) into the tube, which is held a little inclined from the perpendicular at first in order to let the new mercury wash off, as it were, any oxide or amalgam that may have been formed, and which washing may be caught either in the cistern or in some separate vessel; then, when the tube is quite full, to close it with the end of the middle finger so as to prevent the escape of mercury, and, so closed, to invert the tube and plunge its end in the cistern, withdrawing the finger under the mercury cautiously so as to moderate the descent of the column in the tube. Then the basket-handle ring is suspended on the hook before-mentioned, and the tube is ready to be measured. For this measurement, the scale is next applied by slipping the ivory float over the lower end of the steel rod, passing its lapped end through the appropriate opening in the bracket, catching it there with the nut, and working the nut up or down until the mark on the lower end corresponds with the

fiducial edge of the float. The distance apart of the holes in the bracket, and the width of the graduated curved plate, are such and so proportioned that when the tube and rod have been fastened in the position indicated, the curved index projecting, as seen from the vernier plate, embraces without touching the tube, and can be readily brought, by means of the vernier-rack, to a due coincidence with the top of the column, and the reading of the scale then made. When the instrument is to be taken down, the various motions that have been described have to be made in a reversed order. For ascertaining the temperature of the mercury a loose thermometer is either stood in the cistern, if the sides of that vessel are high enough to retain it, or is hung from the bracket by a suitable string or wire that allows it to plunge properly into the cistern. This method of ascertaining the temperature is a normal peculiarity in this arrangement, as will be spoken of more particularly presently when the correction for temperature comes to be discussed.

Alexander's Barometer.—The same mode of applying the thermometer is found in another arrangement by J. H. Alexander, which presents some other peculiarities that appear to have recommended it to frequent employment. This, like the former, consists of a naked tube, whose open end, terminated with a slip of platinum welded on the inside for a purpose that will be presently spoken of in relation to deterioration of barometers, bears also a sort of flat cistern which is permanently full of mercury, and which is shown in the adjoining Fig. 328. This cistern is formed as follows:—First, a collar of iron is cemented on the outside of the tube near its extremity, to which is screwed permanently a bell-shaped dish of iron open at bottom. The bottom is then closed by a sheet of Russia iron thinned by hammering and then annealed until it has become extremely flexible, which is cut round to fit on a rebate within the dish, and is then firmly held there by a ring of iron which screws inside of the dish and up to the rebate. A hole which has been drilled horizontally, Fig. 329, into the side of the dish, is closed by a screw-plug, which admits of removal at discretion, and which, when removed, allows the mercury to

Fig. 328.



flow inward or outward of the dish. The object of all this apparatus is to have both the dish and the tube quite full of mercury when the instrument is not up for use; and the elastic bottom is intended to provide for the expansions and contractions which take place upon change of temperature, to which the mass is always more or less subject. The diameter of the bottom, therefore, is proportioned to the capacity of the tube and dish in such sort that the known elasticity of the sheet is capable of adapting it in close contact with the mercury within through a range of 60° on each side of the normal temperature, which may be taken at from 60° to 62° Fahr. Such close contact may be expected to be favorable for the exclusion of air.

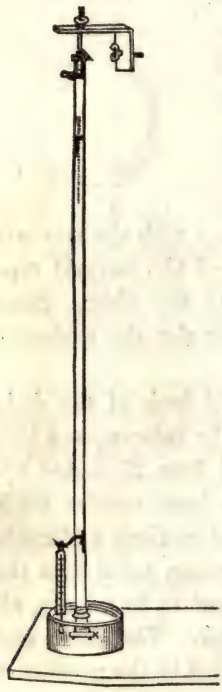
Fig. 329.

At any convenient point, say within a half inch of the dish, the zero of the graduation is marked on the tube, upon which also the division of the graduation is marked from 25 inches upwards to 31 inches for every one-tenth. A loose vernier made of pearl (both for its transparency and ease of motion), and made to hug the tube closely by a circular steel spring, subdivides the graduation to $\frac{1}{100}$ of an inch, which is supposed to be minute, all things considered, as there is any necessity for. The closed end of the tube, which is shrunk and then swelled in the process of sealing, receives, when the instrument is set up, and is embraced by a steel collar capable of being drawn tight by a screw, and having a sort of basket-handle, as in the Hassler barometer, a suitable iron bracket, with a hook and nut for elevating or depressing the tube when suspended, and with a gimlet screw that serves for either extempore or permanent fastening of the bracket, provides the means of support both for the tube and for the thermometer, as in the former case; and finally, an ivory float, shaped like a hat without a crown, and which is to be slid over the tube before the collar is put on, and whose base must correspond to the zero of graduation, completes the means of adjustment, Fig. 331. In order to effect this correspondence, another mark has been also placed upon the tube a certain dis-

Fig. 330.

tance, say a half inch above zero, exactly equal to which distance is made the height of the float before-mentioned from its base to its fiducial edge. Of course, when said fiducial edge is adjusted to the mark in question, the base of the float is at zero. And as this base is in contact with the surface of the mercury in the outer cistern or cup, the same adjustment determines the mercury-surface as being at zero likewise.

Fig. 331.



When the instrument is to be set up, and is just taken out of its packing-case (which is a wooden sheath suitably lined), with the cistern end uppermost, it is inverted, and held at an angle of about 50° with the horizon, its cistern is plunged above the zero mark into a convenient cup, or basin, or outer cistern, containing mercury. The screw-plug is then extracted under the mercury by means of an appropriate hook, Fig. 332, in order to avoid soiling the metal by touching with the fingers; and the outward flow of the column and its descent regulated by carefully raising the tube to the vertical. The float is then slid over the tube; the collar screwed on; its basket-handle caught by the hook in the bracket previously fastened at a proper height above the cup; the vernier applied; the thermometer immersed in the mercury of the cup; and after five minutes, to allow of its assuming the temperature of the fluid, the column is ready to be measured.

Fig. 332.

When the instrument is to be taken down, the same steps are gone through in a reversed order; the chief caution necessary being to see that the tube is quite full to the very top (as it always becomes at the suitable inclination) before the screw-plug is inserted, and to insert said plug while the aperture for it is beneath the surface of the mercury.

Such are the principal modifications of cistern barometers requisite to be mentioned. Of the other groups,—the syphon-

barometers,—a sufficient type may be found in the only one that will be described, viz., Gay-Lussac's Barometer.

Gay Lussac's Barometer.—Of this form of instrument, disembarrassed of its casing, the adjoining sketch will give a satisfactory illustration; where it is seen to be composed of two pieces of an ordinary barometer-tube, together surpassing 33 or 34 inches, and connected by a re-curved piece of glass tube with a very small bore, the object of which is, by increasing the friction as well as diminishing the mass of the column, to diminish also the strain or shock that would follow every brusque movement. The instrument originally is supplied with mercury, rather more than enough to fill the upper large tube and the capillary-tube, including its bend. When the instrument is reversed with said bend uppermost, the mercury fills the bend itself entirely, thus excluding the entrance of air, and the surplus metal drops into the end of the tube near *o*; at which place there exists a small orifice for the admission of the atmosphere to press on the column, and even for additions of mercury if desirable, but too small and introverted to allow the escape of the fluid from within in any of the reversals which the instrument may undergo. The sketch, Fig. 333, shows the apparatus in its direct position, when the column in the upper tube will have fallen to say *s*, and will stand in the lower one at say *t*. It is evident that the vertical distance between the surfaces at these two points is the height of the column of mercury which equilibriates the pressure of the atmosphere. To measure this there are various ways, as well when the necessary graduation was inscribed as at first upon the glass as when it is marked on the other brass tube, which embraces and protects it. The most usual is to take a zero midway between the two surfaces, as at *z*, and to graduate upwards and downwards from that origin. A movable vernier is attached to each scale, which is adjustable to the surfaces respectively, and subdivides the direct readings: the sum of the two readings is the height of the column sought.

Fig. 333.

The instrument is enclosed, together with a thermometer lying along the limb *s z* (or sometimes the thermometer is unattached), in a brass tube, which is slotted for some distance along both limbs to allow the surfaces to be seen by transmitted light, which

slots are coverable with a portion of another tube moving horizontally, and serving as a screen, as in the instance of the wooden-cisterned and cased barometers spoken of just now. So arranged, it is ordinarily capable of enduring all careful transportation and even ruder treatment, and forms one of the neatest and most convenient portable barometers. In a laboratory, however, where this feature is not essential, one of its necessary defects become more conspicuous, viz., that it requires two readings, and thus doubles the time and trouble of observation.

If but one arm were read, it is obvious that the scale would indicate but one-half of the change of level which may have taken place from one epoch of observation to another; for of the total actual movement of the equilibriating column, equal parts, whether of elevation or depression, will be borne in just reciprocal senses by the columns in the two limbs. And in so far the errors of reading, whatever they might be, would be multiplied. The chances of such multiplication are diminished upon the double reading, if we suppose that the errors are liable to occur in the same way, as is most likely. If such supposition is not correct, then the error of reading will be of course multiplied.

Such errors, which are always possible, partly from the nature of the apparatus and partly from a personal proclivity varying both in its direction and its amount of the observer, are always to be guarded against; and this aim has led to sundry devices for enlarging the scale, and thus virtually dividing its errors. The wheel-barometer, which has already been mentioned, is one such device; where a range of one inch, for instance, in the vertical column is multiplied, as it were, in the revolution of the index over a circumference of eighteen inches. A similar contrivance, applicable to the syphon barometer, is, instead of letting the float-string be connected with a pulley to attach it to the short arm of a balanced lever, whose other arm may bear any assignable proportion in length to said short arm, and the circular scale travelled over by the extremity of which will be, of course, expanded in the same proportion.

Morland's Diagonal Barometer.—Another contrivance for the same purpose is the so-called *diagonal* barometer of Morland, in which the upper part of the tube instead of continuing vertically is inclined to the horizon at any angle, and the scale is applied

to the inclined limb. It is clear that the tube must be made longer than the ordinary vertical one, in the ratio of the angles of inclination, and that the divisions of the inclined scale will be to the normal ones of the vertical scale in the proportion of the cotangent of those angles respectively to radius. Another method is that exhibited in the *rectangular* barometer, as it is termed, where the mechanical arrangement is in some sense the converse of the last, viz., the open end of the tube is bent for an indefinite extent at right angles to the vertical. But here the multiplication of the reading is in the ratio of the square of the bore of the vertical and horizontal tubes respectively; and the disparity of bore is either produced by enlarging considerably the vertical bore through the range of its possible variation, or by diminishing the bore of the horizontal tube until it becomes even capillary. If, for instance, the vertical bore be 0·40 inch, while the horizontal is 0·05 inch, it follows that the longitudinal spaces to contain equal quantities of mercury must be 64 times as great in the latter as in the former. Of course the scale is multiplied in the same ratio. In this arrangement, the smaller the calibre and the more the tube is kept perfectly horizontal, the less occasion there is for a cistern; the pressure of the atmosphere upon the face of the mercury at the open end being always sufficient to prevent any extravasation. Such extravasation will not take place even with the swelled vertical bore, under ordinary circumstances.

This principle of varying the bore of the tube, so as to produce motion through unequal lineal spaces, coupled with another of using fluids in conjunction with mercury of vastly inferior specific gravity, water, tartrate of potassa in solution, petroleum, &c., has been very fruitful in suggesting modifications for expanding the scale; and the names of eminent geometers, such as Des Cartes, Huggens, and Hooke, are still connected with arrangements to this end, upon which they exercised no inconsiderable ingenuity in invention or improvement. But the description of these is unnecessary here; for at the period of their suggestion the application of the barometer, as an instrument of research, was limited and partial, and its destiny but vaguely anticipated, so that a cumbrousness, which would now be found intolerable, was then but an inconsiderable defect, while the very amplifica-

tion of scale by the means resorted to, though there was nothing left to be desired as to minuteness of reading, introduced errors of another and more radical kind, of which there was at that earlier period no suspicion.

Water Barometer.—How far certain modern arrangements with the same aim are to be classed in the same category can only be judged of negatively, in consequence of their limited acceptation. So, for instance, the great water barometer, erected some twenty years since for the Royal Society of London by Mr. Daniell, remains yet, as far as known, unimitated. The extreme mobility of the fluid used in this, and the magnitude of its scale, —more than thirteen times that of a mercury column,—render its oscillations as frequent as every successive breath of air and as capricious; while the evaporation going on from its surface no doubt fills with an atmosphere, though of low tension, the space that ought to be a perfect vacuum. So, too, the sulphuric acid barometer first constructed many years since, and recently repeated in an apparatus at the Smithsonian Institute.

The difficulties which have attended attempts to expand the scale of the barometer in using mercury or lighter fluids, as well as some other practical defects, have led to the employment, or more correctly, the suggestion of substitute apparatus, in which the object has been more or less met by what may be termed indirect methods. Among these may be mentioned—

Adie's Sympiesometer.—This was principally intended to replace the ordinary barometer at sea, where the sudden and violent motions of the vessel render the oscillations of an ordinary mercurial barometer either incapable of being read at all, or not very reliable. These motions, therefore, are sought to be counteracted in such a column by strangulating the tube in some convenient place or places, or zig-zagging it, or twisting it in a spiral after the manner of Passement. But, although the movement of the column may be thus retarded, so as to insure the safety of the instrument and the capacity of its being read, this gain is at the expense of its permanent delicacy and susceptibility to minute atmospheric variations in opposite senses. The aim of the sympiesometer is to cure this last defect also. The instrument itself is bulbed at both ends and syphoned, with the lower bulb open to the atmosphere. The upper bulb is filled with pure hydrogen;

the lower one in part, as well as a portion of the upright tube connecting them, with almond oil colored with alkanet root. It is obvious that as the pressure of the atmosphere upon the oil changes, so, inversely, will the normal volume of the enclosed gas, whose limit is indicated by the surface of the oil column, expand or contract; and that the measure of compression of the gas is thus indirectly a measure of the pressure of the atmosphere. Hence the name, meaning literally "compression-measurers," which has been given to it. The instrument itself is graduated upon comparison with a mercurial barometer supposed to be accurate; and both are so suitably connected with an air-pump as to make an artificial stand in the latter of successively 26, 27, 28, &c., inches, and the cotemporaneous stand of the oil-column is marked on the sympiesometer-scale as corresponding inches respectively. These spaces are then subdivided into $\frac{1}{100}$, which, of course, correspond to 0·01 inch on the ordinary mercurial scale. Further, the volume of the enclosed gas is affected not only by the atmospheric pressure, but also by changes of temperature. To save the necessity of calculating a correction on that account an ingenious contrivance has been arranged, whereby the inches-scale of the column slides with a rack worked by an outside knob along a fixed scale marked for degrees, counting from above downwards. An ordinary thermometer is set in the frame alongside of the oil-tube, and in observing the instrument, a zero or index-mark upon the sliding-scale is made to coincide with the identical degree on the fixed scale which is shown upon the thermometer: the reading of the oil-column upon the sliding-scale is the barometric reading required, reduced to the uniform temperature (32° or 62° F.), which may have been adopted for the calculation of the correction.

There is no doubt of the sensibility of this apparatus to very minute changes in atmospheric pressure; but in consequence of the liability of the gas to absorption by the oil, it is not so certain that the indications remain perfectly uniform during a long period, or that they are permanently accurate.

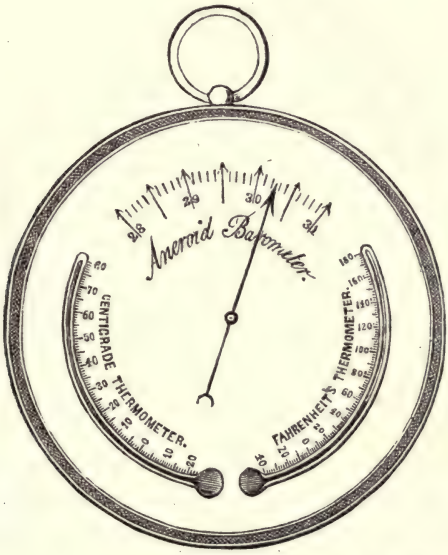
Aneroid Barometer.—This sympiesometric principle has been also applied to another class of devices, known as *aneroid* or fluidless barometers. The first suggestion of such device was about a century ago by Mr. Zeiher, who prepared a hollow cylin-

der, completely freed from air, with two movable ends kept apart by a light spring, which yields as the atmospheric pressure increases, and recovers as that pressure diminishes. This is virtually weighing the atmosphere by a steel yard, whose unavoidable friction would always be a function of the apparent reading; and it seems to have been viewed in that light, and to have remained, on this or some other account, a mere suggestion for another half century, when Mr. Conté took it up afresh, and actually caused it to be executed,—a form which he denominated a vacuum vase. This was a lenticular vase, whose sides below of iron or copper, above of thin sheet-steel, were kept apart by a series of springs. From this vase the air was exhausted, and the vessel soldered up air-tight. The whole weight of the atmosphere then falls upon the flexible steel arch; and as the resistance of the springs was assumed constant, this cover-plate rises or falls as the atmospheric weight varies. These variations are shown by means of an index which vibrates upon a suitable dial-plate. But no provision was made in this for the mechanical effects of change of temperature in altering the resistance of the springs, as well as the proportion of the parts that were concerned in the motion of the index, and the irregularities from this cause forced the ingenious inventor himself to acknowledge the insufficiency of the apparatus.

But, nearly a half century afterwards, another Frenchman, M. Vidi, contrived and announced an instrument to which he gave specifically the epithet *aneroid*, which was just now used here as generic; and in which, by making the sides of the vacuum vase not arched but corrugated, and by introducing within it a permanent gas instead of metallic springs, and by connecting its movement with springs outside, a compensation, in some degree, is demonstrably afforded for variations of temperature. Thus, although under an increased temperature, the capacity of the vacuum vase tends to be itself increased, and so by expanding to cause the index to move in a corresponding direction, the diminution of elasticity, both in the sides of the vase and in the spiral spring seen in the sketch, allows the pressure of the atmosphere to be more effective, so that, in point of fact, the index would move in the opposite direction, were it not checked by the increased tension of the contained gas. This gas tension, then, between the two opposing results of increased capacity of vase

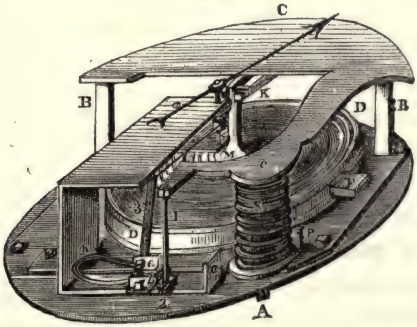
(and thus a lifting of the levers), and of diminished elasticity of springs (and thus their depression), is left to hold the balance, and in its proper apportionment to cause an independent result, which is strictly symmetrical with the variations of temperature to which it is subjected. It is in this way, at least, that the principal manufacturer of the instruments, Mr. Dent, accounts

Fig. 334.



for the regularity with which an aneroid once adjusted follows the corrected readings of a mercurial barometer.

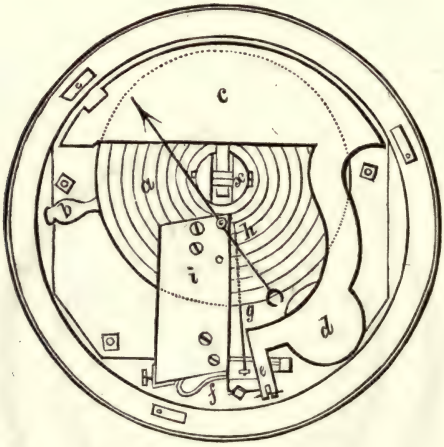
Fig. 335.



The annexed figures 334, 335, and 336, give an outside sketch

of a ground projection and a perspective view of the interior of the apparatus; in which D shows the vacuum-vase, C the lever, which, resting on the fulcrum B at one end, and on the spiral spring S at the other, and keyed at K to the shaft that moves with the motion of the vacuum-vase, communicates that motion

Fig. 336.



through the vertical rod 1, the arbor-levers and bow-piece 2, 3, 4, the horizontal rod and chain to the arbor of the index. This arbor is kept lively, and the faculty of contrary motion in the index maintained by a flat spiral spring, which is seen attached. The readings of the instrument are adjusted to those of a mercurial barometer by means of a screw, which is at the centre of the back of the case, and by the motion of which the index also can be moved. Of the two hands seen on the dial, the steel one is the cursive index; the gilt one is only a register-hand, adjustable by the nut on the outside of the glass, and set at any time to correspond with the cursive, shows, at any other period, the variation that may have taken place in the pressure.

Finally, in regard to the reliability of this apparatus, it must be said that, in spite of the correctness of its theory, and the very ingenious manner in which the mechanical developments have been contrived, it is hardly to be accepted as under all circumstances an invariable substitute for the mercurial column.

Bourdon's Barometer.—The metallic barometer of Bourdon is

an aneroid arranged upon a somewhat different mechanical principle. Instead of the vacuum-vase being a flat cylinder, working by its face as in Vidi's, it is a horse-shoe hollow lenticule, the changes of atmospheric pressure upon which cause the ends or heels of the horse-shoe to approach or recede from one another. These approaches and recessions, themselves very minute, are multiplied by connecting-rods that work a winch-lever, whose shaft is the arbor of a segment of a toothed wheel working into a pinion set on the index arbor.

Wollaston and Regnault's Barometer.—The thermo-barometer of Wollaston, first suggested by Fahrenheit more than a century and a quarter ago, and recently improved by Regnault, and from its presumed special adaptation to the measurement of heights, called the Hypsometric (or height-measuring) Barometer, acts in a still more indirect manner, and furnishes indications that are only hypothetically convertible into equivalents of a mercurial column. It consists of a thermometer with a very open scale (degrees divided to tenths or still lower) which is suitably exposed to the vapor of boiling water, the vessel and lamp for which form part of the apparatus. The thermometer shows, of course, the temperature of the vapor which is formed, and is supposed to show its temperature at the crisis of boiling, when its tension is exactly equal to the atmospheric pressure. If this is so, and if the tension of vapor at varying temperatures were accurately known, or even uniformly stated, by different experimentalists or theorists, and if the observation were momentaneous, or at least but brief, the instrument would be a commendable and valuable one. Actually, however, it is not, in these regards, suitable for use in the laboratory, and, therefore, need not be farther described here.

For the laboratory, an apparatus that would record successive variations in atmospheric pressure would be exceedingly useful; and devices in this aim have been occasionally tried, under the name of—

Register Barometers.—But the friction occurring upon the apparently necessary mechanical arrangements is so great as seriously to impair the delicacy of the instrument, and to prevent the reliable use of any of the contrivances which have been, up

to this time, suggested, and whose description may therefore be spared.

After this account of different forms of barometer, which all require, more or less, the co-operation of a professional artist, it will be well to explain how the experimentalist or student in the laboratory may construct for himself an apparatus, which, with only reasonable skill in manipulation, and ordinary good fortune, will be capable of furnishing results as reliable and convenient as any of the more elaborate arrangements which have been spoken of. For this, a tube is to be selected (and, if possible, from among such as have still both ends sealed), from 0·25 to 0·38 inch bore, as uniform in size, and as free from striæ, and as thin in the material as may be, and to be cut off (according to the methods described for cutting glass tubes) to a length of 33 or 34 inches. The open end is then to be ground off square upon an emery plate. About an inch or an inch and a half from the open end, a suitable mark is to be made with a fine file, to serve as a zero, from which, with a beam compass or an accurate fiducial-edged scale, a space of 27 inches is to be laid off towards the sealed end (care being taken to lay the line as nearly in the axis of the bore as possible), and to be continued inch by inch up to 31 inches; which inch divisions are then to be subdivided from a scale, as mentioned, into tenths. For making these divisions accurately, it is best to coat the part of the tube where they are to fall with a thin layer of beeswax, or a strip of tissue or other thin paper may be laid along the line, and cemented to the tube with lip-glue. Upon the tube so prepared, the divisions in question are first transferred with a pencil, and then cut into the glass, either with a writing-diamond or a dentist's file. Either of these implements will encounter no difficulty in any tube likely to be selected. The tube so graduated is then to be carefully wiped out by means of a screw ramrod, wrapped with dry, clean, old linen, and all specks and adhering filaments are to be removed.

Clean, fresh mercury will then be taken and sifted into the tube against the side of the glass, so as to cause as little spattering and entanglement of air as may be, through a paper funnel of the usual shape, and of a reasonably fine orifice, to a height of 5 or 6 inches above the sealed end; which mercury is then to be

boiled in the tube itself over a charcoal fire, or better, a gas burner of sufficient length to embrace the whole reach towards the end of the operation. It is hardly necessary to advise that, in order to promote the safety of the tube, it should have been gradually warmed up through its entire length before urging the mercury to ebullition. When all bubbles of air cease to be given off, more mercury, previously heated, is to be similarly sifted in to a height of 15 or 18 inches, and treated like the preceding instalment; after which a last addition is to be made, filling the tube to (say) 3 inches of the top, or open end, and boiled as before. Care is to be taken that each successive boiling should be initiated below the joint, as it were, of the successive additions to the column, in order to avoid driving any of the entangled air downwards. The ebullition cannot be effected in the last three inches of the tube; and all that can be done is to sift into that until running over hot mercury, which has been recently boiled in a separate vessel, and to apply below and about the joint as much heat as can be borne without extravasation of the fluid. Placing, then, against the end of the tube, in such a manner as not to cause any violent removals or out-splashings of the mercury, the end of the middle finger, covered with a clean buckskin or kid glove, or, still better, such a padded implement as is figured under the preceding description of the Alexander barometer, the tube is to be inverted and its end plunged in a porcelain or glass cistern, cup, or basin, which has been previously supplied with a suitable quantity of boiled mercury, whose specific gravity has been ascertained and recorded; and when raised vertical, the finger or pad to be carefully withdrawn, so as to let down the column easily and without shock. Then, the tube being held by an assistant, sufficient wire or silk cord is to be wrapped, whipmaker fashion, round the sealed end of the tube, to form a loop for suspension, which loop can be hung upon a hook in a convenient bracket, made as described for the barometer just mentioned, or in the absence of such a contrivance on a permanent hook, in which case the adjustment will be made either in moving the cistern itself by wedges under it, or by adding or withdrawing portions of the mercury within. As the barometer is intended to be stationary, this adjustment once made does not require to be often repeated, though it should be verified for every series of ob-

servations. The easiest way of making such adjustment is by the ivory float already described, the fiducial-edge in the notch of which is to be made to correspond with a mark made on the tube of the same distance from zero as the space between said edge and the base of the float; the most accurate way is by means of a vertical ivory stiletto, gauged to a certain height on the tube, and attached by a horizontal arm to a metal or ivory collar clamped on the tube after the method of Fortin.

After this adjustment, made in either way, the column can be read directly to inches and tenths, and lower by estimation. To subdivide accurately and directly resort must be had to a vernier, which may be a thin slip of pearl or ivory, or even paper, on which a space of 0·9 inches, or nine divisions of the scale is, by proportional compasses or by any other satisfactory method, divided into ten equal parts. It is manifest that each one of these parts is $\frac{1}{100}$ of an inch shorter than the scale division; that if the zero of the vernier corresponds with any scale-division, such correspondence cannot occur again until its tenth division; and that when the zero does not so correspond, the number of the vernier division, which coincides with some scale division, indicates the number of hundredths by which the zero happens to deviate and exceed the nearest scale division below it. This will be made plainer by reference to the adjoining cuts, in which vernier and scale are represented in the two positions respectively. In (1) the zero of the vernier divisions is seen to coincide with 29·5 on the scale; vern. div. 1 is of course 0·01 in. short of 29·6; vern. div. 2 short by 0·02 in. of 29·7; vern. div. 3 short by 0·03 in. of 29·8; and so on until vern. div. 9 is short by 0·09 in. of 30·3, and vern. div. 10 coincides with 30·4. Now if, as must be universally attended to, the zero of the vernier is adjusted to the level of the mercury in the tube, position (1) gives a reading for the height of the column

Fig. 337.

Fig. 338.

of 29·50 inches. In position (2) the vernier zero presupposed to have been, in like manner, independently adjusted to the mercury-level in the tube, does not happen to coincide with any scale division, but lies rather more than midway between 29·5 and 29·6. In order to see by how many hundredths exactly this zero or mercury-level deviates from and transcends 29·5, the observer looks along the scale until he finds a division there coincident with some vernier division; the number of said vernier division is the number of hundredths in question. It is seen here that division 6 of the vernier coincides with a division (it is immaterial to count which) on the scale, and $\frac{6}{100}$ is therefore the space by which vern. 0 has passed 29·5, and the proper reading is 29·56 inches. If the student is not familiar with vernier reading, and finds a difficulty or want of readiness yet remaining after this attempted explanation, the best method for him is to draw the two scales on separate pieces of paper, so as that one (the vernier) may be applied to and shifted along the other. He cannot fail after a few trials to catch the idea and the knack of this indispensable adjunct, the vernier, in measuring spaces that are too minute for direct graduation.

In the arrangement here given, the reading does not answer for less than hundredths of an inch. Fortunately, a greater minuteness is not requisite in any ordinary physical research; and if it were, there is room to question its attainability otherwise than as a formal precision not a substantial accuracy.

A barometer, made and mounted as recommended, will give better than most of the more elaborate instruments all the indications which are presumed to denote that the essential conditions of a perfect apparatus have been satisfied. These indications are principally the brilliance of the mercurial column, for the observation of which the naked tube affords the utmost scope possible; a peculiar hammer or click made by the impact of the mercury column against the sealed end when the instrument, previously stoppered by the pad or the gloved finger, is lifted out of the cistern and gently inverted, which click cannot be produced if there is any appreciable residual air in the space intended to be vacuous; the adherence of the mercury column to the sealed end when the tube reverts to its erect position, and which sometimes requires a considerable concussion to be overcome; the phe-

nomenon, in the dusk or dark, of luminous green flashes when, the tube being normally suspended and caused to swing through a small arc, the mercury column vibrates within, and electrically excites the tube; and finally, the manifestation in broad daylight of electric attraction and repulsion, when to the tube so swinging a gold-leaf electrometer is presented. By the prevalence of all these signs, the vacuum is judged to be more or less perfect; and when this condition of perfection is attained, all the other details of arrangement are only matters of fancy, convenience, or conservatism.

This last item, to be sure, viz., the conservation of a vacuum once attained is hardly less interesting than the original attainment; and, unfortunately, the deterioration of tolerably good barometers is more frequent, constant, and uniform, than the occurrence of instruments of a higher class. This deterioration, by whatever symptoms manifested, seems to be attributable altogether to the action of the atmosphere, as well chemical as mechanical. The first produces an oxidation of the metal in the cistern (supposing the column entirely exempt from contact with air) which does not fail, after a longer or shorter period, under ordinary circumstances, to be propagated upwards in the tube; the second (under the same supposition) is always active in insinuating minute portions of air, favored by every oscillation of the column and the motion of the tube, downward along the outside, and upward along the inside of the tube. If the assumption of a perfect vacuum within does not hold in fact, of course the operation, in the first mentioned mode, and possibly also in the second, is proportionally facilitated. It was at one time supposed, upon authority no less high than Davy himself, that atmospheric air was always combined, as it were, vesicularly in every mass of mercury, and that all attempts to expel it by heat or withdraw it by exhaustion would be ineffectual; but the later experimental researches of Daniell have shown that this supposition was an error, and that the attraction between the mercury and the accidentally contained air is not difficult to be, by proper means, entirely overcome. The air, then, which deteriorates the vacuum and spoils the column, creeps in from without; and when it is considered that there is no liquid contact between the metal and the glass,—no *wetting* of the latter by the former,—one can

readily see that in the finite space which always thus occurs between the two surfaces at every point of the immersed part of the tube there is ample room for air to insinuate itself between them, and thus to leak into the tube. With respect to oxidations within the tube, which manifest themselves by a loss of brilliance of the column though its smoothness, is still maintained, they may, in some cases, arise from a partial amalgamation with the lead used in the composition of the glass. When there is opportunity for this, the disorder is hopeless, and after it has reached a certain point the barometer is no longer reliable, and the tube should be rejected. But, with respect to leaks occurring round the open end of the tube, the platinum guard spoken of under the Alexander barometer, and whose suggestions arose with Mr. Daniell, appears to present a full remedy. The amalgamation which takes place with platinum is very slight and slow, the amalgam itself of great specific weight; an air-tight liquid contact is therefore effected along the whole width of the platinum strip, and whatever amalgam may at any time be detached, tends to the bottom of the cistern instead of ascending like the lead amalgam to the surface.

The opinion just now referred to, of an indestructible combination between mercury and certain finite portions of air, had its influence at the time upon the question of boiling the mercury in the tube, as a means of obtaining a more complete and permanent vacuum; and those who objected to the boiling, on the score of its undoubted trouble and risk, were all the more fortified in their objections by the conviction of its inutility. But the researches of Mr. Daniell have almost dispelled such convictions; while they have also brought to light an important advantage to be derived from boiling, viz., in diminishing the correction that has to be applied for what is technically called *Capillarity*. This term, although not literally, is yet physically applicable as well to barometer tubes of the largest ordinary bore as to those minutely pierced stems, whose hair-like orifices are properly and strictly to be named *capillary*, and the correction is necessary in both to compensate for the effect arising from the relative attractions reciprocal between the tube and the enclosed fluid, and existing among the molecules of the fluid themselves. If the physical sum of these attractions respectively be equal (or, to speak geo-

metrically and with more precision, if the intensity of the attractive force of the matter of the tube is half of that of the fluid) the surface of the column will of course be plane and horizontal, there being no force to solicit it towards any other form. If the attraction of the tube be null or very small compared with that of the fluid, the surface will be convex and nearly hemispherical, its radius of curvature increasing with the tube-attractiveness, while that of the fluid remains constant, until the former element becomes equal to half the latter. From this epoch, which is that of horizontality, if the tube-attractiveness goes on increasing, the surface becomes proportionately concave, and attains hemisphericity when the intensities of the respective forces are numerically equal. Hence, with mercury, upon which glass exercises little or no force of attraction, the surface of the column is convex, and is depressed, or, as it were, repelled below its proper and otherwise normal level. With water, on the other hand, oils and all liquids which *wet* glass, the surface is concave, and is elevated above said normal level.

As the attractions in question are not sensible through spaces which are considerable, and, in point of fact, are inappreciable at appreciable distances, their effect will be proportionate to the diameter of the tube, and when that diameter surpasses (say) 0·75 inch it becomes insensible, and the correction unnecessary. But, in any case, if the diameter be assumed uniform (for otherwise there would be successions of varying equilibrium, stable and unstable, in the tube) as well as the quantities of the respective intensities, the amount of the correction is theoretically capable of calculation, and, if suitable experimental data be substituted, of numerical definition. Such definition is to be found in the following table, founded on the formula of Laplace, and the observations of Gay-Lussac and Haüy, calculated by Bouvard, and here for the first time reduced and interpolated for English measures.

CORRECTIONS FOR CAPILLARY DEPRESSION IN BAROMETER TUBES.

	TUBE.			TUBE.	
Bore.	Unboiled.	Boiled.	Bore.	Unboiled.	Boiled.
In.	In.	In.	In.	In.	In.
0·16	0·080	0·040	0·22	0·050	0·025
0·18	0·068	0·034	0·24	0·044	0·022
0·20	0·058	0·029	0·26	0·038	0·019

Bore.	TUBE. Unboiled.	TUBE. Boiled.	Bore.	TUBE. Unboiled.	TUBE. Boiled.
In.	In.	In.	In.	In.	In.
0·28	0·034	0·017	0·46	0·014	*0·0055
0·30	0·030	0·015	0·48	0·010	0·005
0·32	0·026	0·013	0·50	0·009	0·0045
0·34	0·023	0·0115	0·52	0·008	0·004
0·36	0·020	0·010	0·54	0·007	0·004
0·38	0·018	0·009	0·56	0·006	0·003
0·40	0·016	0·008	0·58	0·0055	0·003
0·42	0·014	0·007	0·60	0·005	0·003
0·44	0·012	0·006			

The 3d and 6th columns of this table are in accordance with Mr. Daniell's observations, which authorize us to conclude that the effect of boiling in the tube is to augment the attraction of the tube for the mercury (probably by causing a more intimate contact), and thus to diminish the correction, as nearly as may be, to one-half of what would be required in unboiled tubes. These last columns, then, are what should be used in the laboratory.

It is hardly necessary to say, that with a syphon-barometer a correction of this kind is not applicable, provided the bore of the two arms be the same. And it is as little proper here to discuss a suggestion which readily follows what has been said, viz., that with a cistern-barometer of the kind recommended just now, it would not be difficult, under given conditions of bore and cistern-diameter, to give such a weight to the float as to correct mechanically the capillary depression, or, what is still easier, provided the fact be noted on the instrument to make the corresponding correction, either in the zero of the graduation or in the height between the bore and the fiducial-edge of the float.

There is another correction which cannot, in the same or any other way, be dispensed with or obviated, and which is necessary to compensate the increased height and expansion of the mercurial column by heat, in order, first, for any individual observation to reduce the apparent reading to what it would have been had there been no change in the volume of the mercury, and thus show the height of column which at the normal specific gravity equilibriated the atmosphere; and secondly, to yield observations which, whether at the same place, but at different temperatures, or at different places either at the same or at different tempera-

tures, are thus made fairly comparable. This is best done by a table like the following:

BAROMETRIC CORRECTIONS FOR TEMPERATURE.

Therm. Fahr.	BAROMETRIC COLUMN.							
	28 in.	28·5	29 in.	29·5	30 in.	30·5	31 in.	31·5
	In.	In.	In.	In.	In.	In.	In.	In.
0°	0·077	0·078	0·080	0·081	0·082	0 084	0·085	0·086
5	0·065	·066	·067	·068	·069	·071	·072	·073
10	·053	·054	·055	·056	·057	·058	·058	·059
15	·041	·042	·042	·043	·044	·044	·045	·046
20	·029	·029	·030	·030	·031	·031	·032	·032
25	·017	·017	·017	·018	·018	·018	·019	·019
30	+ 0·005	0·005	0·005	0·005	0·005	0 005	0·005	0·005
35°	— 0·007	0·007	0·007	0·008	0·008	0·008	0·008	0·008
40	·019	·020	·020	·020	·021	·021	·021	·022
45	·031	·032	·032	·033	·033	·034	·035	·035
50	·043	·044	·045	·046	·046	·047	·048	·049
55	·055	·056	·057	·058	·059	·060	·061	·062
60	·067	·068	·070	·071	·072	·073	·074	·076
65	·079	·081	·082	·083	·085	·086	·088	·089
70	·091	·093	·094	·096	·098	·099	·101	·103
75	·103	·105	·107	·109	·111	·112	·114	·116
80	·115	·117	·119	·121	·123	·126	·128	·130
85.	·127	·130	·132	·134	·136	·139	·141	·143
90	·139	·142	·144	·147	·149	·152	·154	·157

In constructing this table, the melting-point of ice, or 32° Fahr., has been taken as a standard of temperature to which the observations are to be reduced. For all temperatures below 32° the corrections shown in the table are *additive* to the actual reading; for all above 32° they are *subtractive*. The temperatures are given only from 5° to 5°; for any required, it will be sufficient to take proportional parts of the differences between the two corresponding nearest corrections, above and below; for which purpose it is that the quantities are expressed in thousandths. Similar proportional parts may be taken as between the columns nearest above and below to the actual barometric reading; but this is by no means necessary in ordinary cases. The quantities in any column rule for any barometric stand, at or above the caption there, until it attains the next half inch in the adjoining one. Thus, suppose it be required to correct a reading of the barometer of 29·75 made at 68° F. Look in the col. of 29·5, the nearest one below, where the corr. for 65° is seen as 0·083 in., while that for 70° is 0·096 in., and the difference between the

two quantities is 0·013 in., corresponding to 5°. The proportional parts, then, for 3° (the diff. between 65° and 68°) will be ($\frac{3}{5}$. 0·013 =) 0·004; and (0·083 + 0·004 =) 0·087 is thus found for the tube correction, and (29·75 — 0·09 =) 29·66 the corrected reading reduced to 32° F. If it be desired to have the reduction for some other standard than 32°, the table will still serve for any case where very minute precision is not required, if used, as it were, by double entry, that is, reducing at first to 32° by subtracting, if the temperature is above, and *vice versa;* and then raising that reduced temperature to the standard in question by reversing the process. So, if it be required to reduce the reading given just now to say 62° F., the process has already given 29·663 as at 32°; the correction tabulated for 60° is 0·071, and the proportional part for 2° is ($\frac{2}{5}$. 0·012 =) 0·005, making the whole correction 0·076, which, added to 29·663, gives 29·74 as the corrected reading for a temperature of 62°.

CHAPTER XX.

SOLUTION.

When a substance added to a liquid is wholly or partially taken up by that liquid, it is said to be soluble therein. The liquid employed is termed the *solvent*, and its combination with the dissolved particles, a *solution;* and if the liquid has exerted its solvent power to the fullest extent, then the solution which it forms is said to be *saturated*, because it can hold no more.

The variable degree of solubility in different liquids serves as a distinctive characteristic of bodies, particularly those which are solid.

Solution is either wholly mechanical, or else chemico-mechanical.[1] In the first case, it is a molecular division of a body, or, in other words, a diffusion of its particles in an appropriate liquid without any alteration of its original properties, save as to form

[1] Many chemists contend that "*all solution is chemical union;*" and on this point the reader is referred to a paper, by T. S. Hunt, in Silliman's Journal for January, 1855.

and cohesion. Thus, for example, an aqueous solution of sugar or salt yields the whole of its charge by EVAPORATION, and one of sulphate of lime by the addition of alcohol, in which it is insoluble. Ethereal or spirituous solutions deposit their dissolved matter by DISTILLATION or CRYSTALLIZATION; and some other kinds, that of gutta-percha in chloroform, for instance, by PRECIPITATION with ether or alcohol. When the dissolved particles are thus recoverable again in an unaltered state, chemically considered, their solution may be styled *simple.*

In the second case, chemico-mechanical solution, in contradistinction to that which is purely mechanical, is a process requiring the modification of a body by chemical action previous to its solution. Thus, for example, copper, iron, or any other base or acid, insoluble in the ordinary solvents, may be readily taken up by liquid acids or bases. But the liquid holds in solution a newly formed body entirely dissimilar to the original substance in properties, as appears when it is separated. In this, therefore, consists the difference between a simple or mechanical and a chemico-mechanical solution. As examples of this latter, iron may be dissolved in dilute sulphuric acid, but in the act is transformed into copperas; alkalies are taken up by acids, but become altered to salts; and oil in being dissolved by potassa solution is changed into soap. Hence it is that the chemical reaction is a preliminary step requisite to promote simple solution. The point of saturation in chemical solution is that at which the two bodies, invariably of opposite properties, have combined in proportions adequate to *neutralization.*

There are some exceptions to the above, which refer to certain instances in which the acids and alkalies act as mere simple solvents, and without changing the original properties of the dissolved substance. For example, acetic acid dissolves certain phosphates and borates; aqua ammoniæ takes up carmine; potassa water the hydrated peroxide of tin; and hydro-sulphuret of ammonia the deutosulphuret of iridium.

Solution is one of the most important processes in chemistry; it not only facilitates chemical reaction, but allows the separation of soluble from insoluble bodies, or parts of the same; and consequently the purification of the solution by subsequent FILTRATION, EVAPORATION, and CRYSTALLIZATION.

As regards the power of dissolving the greatest number of substances, water is the first in the rank of simple solvents, alcohol the next, and ether third. Then follow spirits of turpentine, pyroxylic spirit, the volatile and fixed oils, chloroform, benzole, and a host of other liquids suitable to particular substances. Of the alkalies, aqua ammoniæ or potassa are most used; the former preferably, because of its volatility and that of most of its salts. All of the common acids are employed, though some few only are of general application: such as the muriatic, nitric, sulphuric, acetic, and tartaric.

When the solubility of bodies is spoken of, it is in reference usually to water, that being the standard liquid. In testing the solubility of a substance, it is, therefore, usual to commence with that liquid, and if it fails, to proceed with the next in order; and always, for reasons below given, trying the experiment at varied temperatures, with gradually increased quantities if necessary.

A very convenient way of testing the solubility of a substance is by means of a test-tube. If solid, a small portion in powder is to be introduced and covered with distilled water, or the solvent to be used, and repeatedly agitated by the hand, the forefinger closing the mouth (Fig. 339) to prevent the escape of particles. If the matter is wholly soluble, there will be no deposit at the bottom of the tube; if partially soluble, the substance will have decreased in bulk; if totally insoluble, it will occupy the same space as at first. To determine as to the two latter results, a minute portion of the supernatant liquid is decanted and evaporated in a small platinum spoon or strip of window-glass over the spirit-lamp (Fig. 151); if a residue remains it indicates that matter has been taken up.

Fig. 339.

When heat is required, the lamp (as at Fig. 153) affords a convenient means of application. The procedure in such cases is the same as that above directed.

Volatile matters can in this way be recognized by their odor emitted at boiling temperature, or else by the taste which they impart to the liquid, or by some other characteristic test.

The solubility of a solid body may be quantitatively determined by measuring out a given volume of the solvent liquid, and adding to it, while boiling, a weighed portion of the substance in question. After the liquid has perfectly cooled, it is to be filtered upon a counterpoised filter. The filter, on being perfectly dried in vacuo and weighed, will give the insoluble residue, which, deducted from the original weight, leaves figures that express the soluble quantity.

The solubility of a gas may be ascertained by passing up a given volume of water, or other fluid, the solvent power of which is to be determined, into a graduated tube filled with mercury and inverted, and then introducing similarly measured volumes of the gas. When absorption ceases, by bringing the interior and exterior levels nearly even, allowing for the small column of water, the remaining gas subtracted from the whole amount introduced will show how many volumes have been absorbed; and knowing the relative sp. gr. of the gas and water, the volumes may be calculated to weights.

1. There are certain conditions which greatly facilitate the solution of substances:—1st, comminution, which increases the extent of surface; 2d, agitation, which promotes the frequent contact of all parts of the surface with fresh portions of solvents; 3d, the freedom from impurity of both the solvent and body to be dissolved; 4th, it is also influenced by the quantity and state of dilution of the solvent; 5th, by the temperature; 6th, by the mode in which the process is conducted.

2. Agitation is effected by stirring with glass rods when the containing vessel is open at the top. The rod should be rounded at the end over the blowpipe flame, and to prevent its rolling from the table or top of the vessel upon which it should be placed, may be square instead of cylindrical as is usual. A very convenient and effective mode of bringing all portions of the liquid successively in contact with the substance to be dissolved, is to place the latter in a cullendered diaphragm suspended beneath the surface of the liquid. The first stratum of liquid in becoming saturated increases its density, and consequently descends and displaces a lower and fresher portion, which, being in the same way surcharged in its turn, gives way to successive strata, and so the operation continues until the whole of the matter, or so much

as can be, is taken up. This mode keeps the substance in constant contact with new portions of liquid, and is, in fact, a kind of *displacement* process.

When flasks or bottles are used the same effect may be produced by repeated shaking.

TRITURATION in a mortar and alternate decantation and fresh additions of the solvent greatly facilitate the solution of solid substances.

3. The purity of the solvent is an important consideration, for if it contain foreign matters, they may impart a dissolving power, which is not inherent in the pure liquid, or diminish that already possessed by it. Faraday makes the following excellent remarks upon this subject.

"It is necessary that the student be on his guard respecting certain variations in the solubility of bodies, arising from the presence of other matters. He will continually find that small portions of substances generally considered as insoluble in water will remain in neutral solutions when some other substance is present, or because of slight mutual decomposition; and he will also frequently find that matter usually considered as readily soluble, is so with difficulty when in contact with substances with which it is not apparently in combination. Thus water boiled upon muriate of potash and phosphate of baryta will be found to contain more baryta than if boiled alone upon the phosphate; and, on the contrary, if oxide of iron and alumina be precipitated together from a solution, it will be found much more difficult to dissolve the alumina by solution of potash than if it had been thrown down alone.

"The alkaline earths are remarkably soluble in solutions of sugar, and also, though to a less degree, in solutions of extractive and other vegetable matters; hence they are retained in solution at times in very unexpected situations, and might give rise to much uncertainty in the appearances and characters of other substances, unless the experimenter were aware of the general fact. Platina is not itself soluble in nitric acid, even when spongy and in its most comminuted form, but when alloyed in small quantities with metals dissolved by that acid, it becomes soluble with them, and in consequence appears now and then in situations where it is not expected. Tartaric acid or tartrates

have an extraordinary power in rendering many metallic oxides soluble, which are not so by other acids without it; and still more in holding them in solution when such substances are added as in ordinary circumstances effect their separation. The oxides of bismuth, antimony, tin, and titanium, are easily dissolved by acids when tartaric acid is present; and being present, ammonia no longer has the power, upon its addition, of separating the oxides of iron, titanium, manganese, cerium, cobalt, nickel, lead, antimony, and the earths, alumina, magnesia, and yttria, from their solutions, and in certain cases even potash or soda fails so to do. Great advantage may be taken of this property occasionally, but sometimes it is equally disadvantageous in preventing the usual action of reagents."[1]

4. In regard to the quantity and state of dilution of a solvent, it must be remembered that some substances require more of it than others for their solution, and that it should be in a greater degree of dilution. Therefore, in examining the solubility of a body always commence with small quantities, and increase both quantity and strength gradually as may be required.

5. Temperature exerts a considerable influence in the solution of bodies; and though in a few instances, as in the solution of lime, magnesia, and anhydrous sulphate of soda in water, its elevation impairs the power of the solvent, yet as an almost universal rule it facilitates its action. The temperature must be adapted to the nature of the solvent and the substance to be dissolved, and of the solution formed.

It may be as well to mention that the caloric rendered latent at the moment of the liquefaction of a solid, which is being dissolved in a liquid, causes a decrease of temperature. Solution in volatile liquids should be in most cases performed in the cold, and when of small quantities in narrow-necked flasks.[2] If heat is required, especially when the vapors are inflammable, a retort or covered still must be used; and if the distillate is valuable, a recipient may be annexed to receive as much as comes over.

[1] Annales de Chimie, xxiii, 356.

[2] When weighed quantities are to be transferred to a flask or other narrow-mouthed vessel, the use of a barrel will prevent liability of loss. Any particles that may adhere to the side of the funnel can be washed down with portions of solvent.

6. The mode of effecting solution varies with the substance under process: MACERATION, DECOCTION, INFUSION, DIGESTION, BOILING, and DISPLACEMENT, have each and all appropriate application.

In ordinary solution the solid should be added in portions, and a sufficient interval allowed for the solution of those in the liquid before fresh are added.

The containing vessels should be those which resist the action of heat, acid, alkalies, and corrosive liquids.

For solution in the cold, or at slightly warm temperatures, jars of hard German glass, or beaker glasses, Fig. 340, are very appropriate vessels. The material in powder is added to the fluid in the jar, and contact of fresh surfaces promoted by stirring with a glass rod. If the liquid solvent is volatile, a glass-stoppered bottle is a convenient substitute for the jar, agitation being effected by shaking it to and fro.

Fig. 340.

Some volatile substances, which are insoluble in water under ordinary circumstances, are taken up by it in the state of vapor. For this purpose both should be distilled together.

When solutions, emitting corrosive or disagreeable fumes, are being made in open vessels, the operation should be conducted under a hood, the barrel of which connects with the chimney-flue so as to insure their exit.

For making *saturated* solutions of most substances, EBULLITION is necessary. For this purpose the solid must be boiled with the solvent until the latter, on cooling, deposits some of its charge. The cooled solution is then to be filtered.

Metals in their free state are dissolved one in the other by FUSION.

Solution of Liquids.—Agitation of the liquid to be dissolved together with the solvent generally effects solution. If upon repose there are two layers, then all the matter is not taken up, and that portion which represents the solution must be separated, and a fresh quantity of the solvent added. This process is to be repeated until all, or as much as possible, of the liquid is dissolved.

Solution of Gases.—The generation and absorption of gases are generally simultaneous processes, and have been fully treated of at pp. 340–360. When water is used, it must be distilled and boiled, to expel air. Viscid liquids are not less solvent than others, but take up the gas much more slowly. As a general rule, the capacity of a liquid for a gas is proportional to its rarity. (*Berzelius.*)

Faraday succeeded (*Ann. de Chim. et de Phys.* 3d Series, Vol. 13, p. 121) in liquefying certain gases by the combined aid of pressure and refrigeration, among them olefiant gas, fluosilicic and hydrochloric acids. Alcohol was partially solidified in the same manner. Hydriodic, hydrobromic, and carbonic acids, sulphuretted hydrogen, and ammonia, assumed well-defined solid forms.

The author thus speaks for himself:—"I sought, in the first place, to obtain a very low temperature, and employed for this purpose Thilorier's bath of solid carbonic acid and ether, placing it, however, under the recipient of an air-pump. The bath vessel was an earthenware dish of four cubic inches capacity, and fitted to a somewhat larger dish, with several folds of dry flannel intervening. The mixture lasted for an half hour. By maintaining a constant vacuum, I lowered the temperature to such a degree, that the carbonic acid of the bath was not more volatile than water at the temperature of 86°, for the barometer of the air-pump stood at 28·2 inches, the external barometer being at 29·4.

"This arrangement made, I joined together, by means of corks and stop-cocks, some small glass and copper tubes, so that, with the aid of two pumps, I was able to subject various gases to a pressure of 40 atmospheres, and, at the same time, to submit them to the intense cold obtained under the air-pump, and to examine the resulting effects. As I expected, the cold produced several results which pressure alone would never have done, and principally in the solidification of bodies ordinarily gaseous."

The two pumps, or condensing syringes, used by Faraday, were fixed to a table, "the first having a piston of an inch diameter, and the second one of only half that size; and both were so associated by a connecting-pipe that the first pipe forced the gas into and through the valves of the second; and then the

second could be employed to throw forward this gas already condensed to ten or twenty atmospheres, into its final recipient, the condensing-tube, at a much higher pressure."

Fig. 341.

The condensing-tubes were of green bottle glass, being one-sixth to one-fourth of an inch external diameter, and from one-forty-second to one-thirtieth of an inch in thickness. They were of two kinds, about nine and eleven inches in length; one in form of an inverted syphon, Fig. 341, having the bend cooled by immersion in a cold bath; and the other, horizontal, Fig. 342, having a curve downward, near one end, to be cooled in the same manner. Into the longest leg of the syphon-tube, and the straight part of the horizontal-tube, minute pressure-guages were introduced when required. The caps, stop-cocks, and connectors, were attached to

Fig. 342.

the tubes by common cement, and the screw joints made tight by leaden washers."

The following table (from *Gray's Pharmacopœia*) of the solubility of some of the salts most in use will be found very convenient.

THE SOLUBILITY OF SALTS.

Name of Salt.	Solubility in 100 parts Water		Solubility in 100 parts Alcohol	
	at 60°	at Boiling-point.	at 60°	at Boiling-point.
ALUMINA.				
Acetate of	Undetermined.			
Arseniate of	Insoluble.			
Borate of	Uncrystallizable.			
Camphorate of	0·05.			
Lactate of	Uncrystallizable.			
Muriate of	Very soluble		100 at 54¼°.	
Nitrate of	Very soluble			100
Oxalate of	Uncrystallizable,			2·91
Phosphate of	Insoluble.			
Seleniate of	Insoluble.			
Sulphate of	50.			
Sulphate of, and Potash	5·4,	133·33		
Sulphate of, and Soda	100.			
Sulphite of	Insoluble.			
Tartrate of	Uncrystallizable,		2·91.	
Tartrate of, and Potash	Uncrystallizable.			
Tungstate of	Insoluble.			
Urate and Lithate of	Insoluble.			
AMMONIA.				
Acetate of	Very soluble,		Readily soluble.	
Arseniate of	Soluble.			
Binarseniate of	Soluble.			
Arsenite of	Uncrystallizable.			
Benzoate of	Soluble.			
Boletate of	38.			
Borate of	8¼,			0·416
Camphorate of	1,	33		
Carbonate of (Sesqui)	33 (*Ure*).			
	20 (*Brande*).			
Chlorate of	Very soluble.			
Chromate of	Very soluble.			
Citrate of	Difficultly crystallizable.			
Ferrocyanide of	Very soluble.			
Formate of	Soluble.			
Hydriodate of (or Iodide of Ammonium)	Very soluble.			
Hydrocyanate of	Soluble.			
Hydrosulphuret of	Very deliquescent.			
Hypophosphite of	Soluble and deliquescent.			
Hyposulphite of	Very soluble.			
Iodate of	Sparingly soluble.			
Lactate of	Uncrystallizable.			
Meconate of	66.			
Molybdate of	Soluble.			
Muriate of (or Chloride of Ammonium	36,	100	7·5 at 80° (Sp. gr. of spirits.)	7
			4·75 do. (Sp. gr. of spirits.)	·900
			1·5 do. (Sp. gr. of spirits.)	·872
				·834
Nitrate of	50,	100		19·16
Oxalate of	4·5	40·84		
Phosphate of	25 (*Brande*).			

Name of Salt.	Solubility in 100 parts Water		Solubility in 100 parts Alcohol	
	at 60°	at Boiling-point.	at 60°	at Boiling-point.
AMMONIA.				
Biphosphate of	Less soluble.			
Phosphite of	Very soluble.			
Purpurate of	·0066,	much more.		
Pyrolithate of	Soluble.			
Suberate of	Very soluble.			
Succinate of	Very soluble.			
Sulphate of	50 (*Brande*).	100		
Sulphite of	100 (*Ure*).			
Tartrate of	60·03	304·7		2·91
Tungstate of	Soluble.			
ANTIMONY.				
Acetate of	Soluble. (*Ure.*)			
Benzoate of	Soluble. (*Ure.*)			
Tartrate of	Very soluble. (*Brande.*)			
Potassio-tartrate of	7	50		
BISMUTH.				
Acetate of	Soluble.			
Arseniate of	Insoluble.			
Benzoate of	Soluble,		Sparingly.	
Carbonate of,	Insoluble.			
Chloride of	Deliquescent.			
Nitrate of	Decomposed.			
Phosphate of	Soluble.			
Sulphate of	Decomposed.			
BARYTA.	5 at 50°,	10 at 212°		
Acetate of	88,	96		
Antimoniate of	Insoluble.			
Antimonite of	Slightly.			
Arseniate of	Insoluble.			
Arsenite of	Difficultly.			
Benzoate of	Soluble.			
Borate of	Very sparingly.			
Camphorate of	Very sparingly.			
Carbonate of	Very nearly insoluble.			
Chlorate of	25.			
Chromate of	Very sparingly.			
Citrate of	Difficultly soluble.			
Ferrocyanuret of	·0005.	·01		
Hydriodate of (or Iodide of Barium)	Very soluble.			
Hydrosulphuret of	11,	50		
Hypophosphite of	Very soluble.			
Iodate of	·33	1·6		
Lactate of	Soluble.			
Lithate of	Insoluble.			
Muriate of (or Chloride of Barium) (Anhydrous)	36·8	68·5	1 at 80°, 0·29, 0·18, 0·09 — S. gr. of Spts.	·900, ·848, ·834, ·817
Muriate of (or Chloride of Barium) Cryst.	43 (*Brande*),	78	1·56 at 80°, 0·43, 0·32, 0·06, 0 25 — S. gr. of Spts.	·900, ·848, ·834

Name of Salt.	Solubility in 100 parts Water		Solubility in 100 parts Alcohol	
	at 60°	at Boiling-point.	at 60°	at Boiling-point.
BARYTA.	5 at 50°	10 at 212°		
Nitrate of	8·18 at 58·9°.	35·18 at 214·97°.		
Oxalate of	Nearly insoluble.			
Phosphate of	Insoluble.			
Phosphite of	0·25.			
Pyrocitrate of	·066,	·02		
Sulphate of	Insoluble.			
Sulphite of	Insoluble.			
Tartrate of	Slightly.			
COBALT.				
Acetate of	Soluble.			
Antimoniate of	Soluble.			
Arseniate of	Insoluble.			
Borate of	Scarcely.			
Carbonate of	Insoluble.			
Lactate of	·026 (*Ure.*)			
Muriate, or Chloride of	Very soluble.			
Nitrate of	Soluble,		100 at 54½°.	
Oxalate of	Insoluble.			
Sulphate of	4 (*Brande*),		Insoluble.	
Tartrate of	Soluble.			
COPPER				
Acetate of	(*Ure*),	20		
Antimoniate of	Insoluble.			
Arseniate of	Insoluble.			
Benzoate of	Slightly.			
Borate of	Insoluble.			
Carbonate of	Insoluble.			
Chlorate of	Soluble.			
Chromate of	Insoluble.			
Citrate of	Insoluble.			
Ferrocyanide of,	Insoluble.			
Fluoride of	Soluble.			
Formate of ,	12.			
Hyposulphite of	Soluble.			
Muriate, or Chloride of	Soluble,		100 at 176°.	
Dichloride of	Nearly insoluble.			
Nitrate of	Deliquescent.			
Oxalate of	Soluble ?			
and Ammonia	Soluble ?			
and Potassa	Soluble ?			
and Soda	Insoluble.			
Phosphate of	Insoluble.			
Subnitrate of	Insoluble.			
Sulphate of	25,	50		
Disulphate of	Insoluble.			
Trisulphate of	Insoluble.			
Sulphite of Protoxide,	Insoluble.			
Sulphate of, and Potassa	Soluble.			
and Ammonia	Soluble.			
Ammonia Subsulphate	66·6.			
Tartrate of,	Soluble.			
Bitartrate of	Less soluble.			
Tartrate of, and Potassa	Soluble			

Name of Salt.	Solubility in 100 parts Water		Solubility in 100 parts Alcohol	
	at 60°	at Boiling-point.	at 60°	at Boiling-point.
GOLD.				
Perchloride of	Soluble.			
Protochloride of	Soluble.			
IRON.				
Acetate (Prot.)	Soluble.			
Acetate (Per.)	Uncrystallizable.			
Antimoniate of	Insoluble.			
Arseniate of (Prot.)	Insoluble.			
Arseniate of (Per.)	Insoluble.			
Benzoate of	Insoluble.			
Borate of	Insoluble.			
Citrate (Proto.)	Soluble.			
Citrate (Bi-proto.)	Sparingly soluble.			
Citrate (Per.)	Very soluble and uncrystallizable.			
Ferrocyanide (Prussian Blue)	Insoluble.			
Fluoride of	Insoluble.			
Gallate of Peroxide of	Insoluble.			
Hyposulphite of	Soluble.			
Lactate of Protox. of	Scarcely.			
Molybdate of Protox. of	Insoluble.			
Protochloride of	Soluble.			
Perchloride of	Very soluble,		100 at 176°.	
Nitrate of Protoxide of	Uncrystallizable.			
Nitrate of Peroxide of	Very soluble.			
Oxalate of Protoxide of	Soluble.			
Oxalate of Peroxide of	Scarcely.			
Phosphate of	Insoluble.			
Phosphate of Peroxide of	Nearly insoluble.			
Superphosphate of	Nearly insoluble.			
Succinate of Peroxide of	Insoluble.			
Sulphate of (Cryst.)	76·238 (*Brande*),	333·3		
Sulphate of (dry)				
Persulphate of	Uncrystallizable,		Soluble.	
Hyposulphite of	Uncrystallizable.			
Persulphate of and Potassa	Soluble.			
Persulphate of and Ammonia	Soluble.			
Tartrate (Proto.) of	0·25 (*Dumas*).			
Tartrate (Per.) of	Soluble.			
Tartrate of and Potassa	Uncrystallizable,		Soluble.	
LEAD.				
Acetate (Cryst.)	27 (*Bostock*),	29	12·5. (*Brande.*)	
Acetate (Anhyd.)			Soluble.	
Diacetate of	Soluble.			
Antimoniate of	Insoluble.			
Arseniate of	Insoluble.			
Benzoate of	Insoluble.			
Borate of	Insoluble.			
Carbonate of	Insoluble.			
Citrate of	Nearly insoluble.			
Chlorate of	Soluble.			
Chloride of	3·33 (*Brande*),	4·5		
Chloride of (fused).				
Chromate of	Insoluble.			
Ferrocyanuret of	Insoluble.			
Gallate of	Insoluble.			
Iodide of	0·08	0·5		
Hyposulphite of	Soluble.			

Name of Salt.	Solubility in 100 parts Water		Solubility in 100 parts Alcohol	
	at 60°	at Boiling-point.	at 60°	at Boiling-point.
LEAD.				
Lactate of	Soluble. (*Ure.*)			
Superlactate of	Soluble.			
Malate of	Scarcely.			
Molybdate of	Insoluble.			
Nitrate of	13.			
Dinitrate of	Scarcely at 60°, but much more so at 212°.			
Oxalate of	Insoluble.			
Phosphate of	Insoluble.			
Phosphite of	Insoluble.			
Succinate of	Insoluble.			
Sulphate of	Not absolutely insoluble.			
Sulphite of	Insoluble.			
Tannate of	Insoluble.			
Tartrate of	Almost insoluble.			
and Potassa	Insoluble. (*Berzelius.*)			
LIME.	(*Kirwan.*)			
Acetate of	Soluble,		2·4 at 80° (Sp. gr. of Sprts.)	·900
			4·12	·848
			4·75	·834
			4·88	·817
Antimoniate of	Insoluble.			
Arseniate of	Insoluble.			
Arsenite of	Difficultly soluble.			
Benzoate of	Sparingly soluble.			
Borate of	Very difficultly.			
Carbonate of (Anhyd.)	Insoluble.			
Chlorate of	Very soluble,		Soluble.	
Chromate of	Soluble.			
Citrate of	Nearly insoluble.			
Fluoride of	Insoluble.			
Hypophosphite of	Solubility nearly equal at all temperatures.			
Hyposulphate of	40·65. (*Brande.*)	150		
Hyposulphite of	Very soluble.			
Iodate of	20,	100		
Iodide of Calcium	Deliquescent.			
Malate of	·66,	1·53		
Molybdate of	Insoluble.			
Muriate (or Chloride of Calcium)	200 at 32°. 400 at 60°. almost any quantity at 220°.			
Nitrate of	25,			161·66
Oxalate of	Insoluble.			
Phosphate of	Insoluble.			
Biphosphate of	Soluble.			
Subphosphate of	Almost insoluble.			
Succinate of	Difficultly soluble.			
Sulphate of	0·301 at 50°.			
Sulphite of	12·5.			
Tartrate of	Nearly insoluble at 60°, but ·16 at 212°.			
Tungstate of	Insoluble.			
LITHIA.				
Acetate of	Deliquescent.			
Bicarbonate of	Slightly soluble.			

Name of Salt.	Solubility in 100 parts Water		Solubility in 100 parts Alcohol	
	at 60°	at Boiling-point.	at 60°	at Boiling-point.
LITHIA.				
Borate of	Soluble.			
Carbonate of	1,		Insoluble.	
Chloride of Lithium	Very deliquescent.			
Chromate of	Very soluble.			
Citrate of	Very difficultly soluble.			
Nitrate of	Very deliquescent.			
Oxalate of	Very deliquescent.			
Binoxalate of	Less soluble.			
Phosphate of	Insoluble.			
Sulphate of	Soluble.			
Tartrate of	Easily soluble.			
and Potassa	Easily soluble.			
and Soda	Easily soluble.			
MAGNESIA.				
Acetate of	Very soluble.			
Arseniate of	Deliquescent.			
Arsenite of	Difficultly soluble.			
Benzoate of	Soluble.			
Borate of	Insoluble.			
Carbonate of	Very slightly.			
Chlorate of	Very soluble.			
Chloride of Magnesium	200 (*Brande*),		50, 50 at 80°, 21 25	Sp. gr. of Spts. .547, .817, ·900
Chromate of	Very soluble.			
Citrate of	Difficultly soluble.			
Iodide of Magnesium	Soluble.			
Malate of	3·6 (*Brande*).			
Molybdate of	6·66	8·35		
Nitrate of	100,		Nearly insoluble in pure alcohol. 11 sp. gr. ·840.	
Oxalate of	Nearly insoluble.			
Phosphate of	6·66.			
and Ammonia	Sparingly soluble.			
Succinate of	Uncrystallizable.			
Sulphate of (dry)	33·192,	73·57		
Sulphate of (cryst.)	68·042,	150·71	1 at 80°. (*Kirwan.*)	
and Ammonia	Soluble.			
and Potassa	Soluble.			
and Soda	33·3.			
Sulphite of	5.			
and Ammonia	Difficultly soluble.			
Tartrate of	Insoluble.			
Tungstate of	Soluble.			
MANGANESE.				
Acetate of	3,		Soluble.	
Ammonio-chloride of	Soluble.			
Ammonio-sulphate of	Soluble.			
Antimoniate of	Moderately soluble.			
Arseniate of	Insoluble.			
Benzoate of	Deliquescent (*Brande*).			
Carbonate of	Insoluble.			
Chromate of	Soluble.			
Nitrate of	Very soluble,		Soluble.	
Oxalate of	Insoluble.			

Name of Salt.	Solubility in 100 parts Water		Solubility in 100 parts Alcohol	
	at 60°	at Boiling-point.	at 60°	at Boiling-point.
MANGANESE.				
Phosphate of	Nearly insoluble.			
Succinate of	1. (*Ure.*)			
Sulphate of	31. (*Ure.*) 50. (*Brande.*)			
Hyposulphate of	Deliquescent.			
Sulphite of	Insoluble.			
Tungstate of	Insoluble.			
MERCURY.				
Acetate of (Prot.)	0·16. (*Braconnot.*)			
Acetate of (Per.)	Readily soluble.			
Arseniate of	Insoluble.			
Benzoate of	Insoluble.			
Borate of	Insoluble.			
Bichloride of	6·25 (*Brande*),	33·3	42·6,	85·2
			10·74 at 50°. Sprts. sp. gr. ·915. 43·66 at 50°. Sprts. sp. gr. ·818. (*Graham.*)	
Chloride of	·00833 at 212° (*Dumas*).			
Chromate of	Insoluble.			
Citrate of	Insoluble.			
Bicyanuret of		54		
Fluoride of	Soluble.			
Molybdate of	Very sparingly.			
Nitrate (Prot.)	Soluble and decomposed by excess.			
Nitrate of (Per.)	Do.	do.		
Oxalate of (Proto.)	Scarcely.			
Oxalate of (Per.)	Insoluble.			
Sulphate of (Proto.)	0·20	0·33		
Sulphate of (Per.)	Decomposed.			
Sulphate of (Sub.)	·005	0·33		
Tartrate of	Insoluble.			
and Potassa	Soluble.			
NICKEL.				
Acetate of	Very soluble.			
Arseniate of	Soluble. (*Ure.*)			
Carbonate of	Insoluble.			
Chloride of	Soluble in hot water.			
Nitrate of Protox.	50,		Soluble.	
and Ammonia	Soluble.			
Oxalate of	Insoluble.			
Phosphate of	Nearly insoluble.			
Sulphate of	33·3,	185·71		
and Ammonia	25.			
and Potassa	11·1.			
and Iron	Soluble.			
Tartrate of	Very soluble.			
PLATINUM.				
Protochloride of	Soluble,		Easily soluble, also in Ether.	
Perchloride of	Soluble,			
Protochloride of and Ammonium	Soluble,		Insoluble.	
and Potassium	Soluble,		Insoluble.	
and Sodium	Uncrystallizable,		Very soluble.	

Name of Salt.	Solubility in 100 parts Water		Solubility in 100 parts Alcohol	
	at 60°	at Boiling-point.	at 60°	at Boiling-point.
PLATINUM.				
Bichloride of	Very sparingly.			
and Ammonium				
and Potassium	Very sparingly.			
and Sodium	Soluble,		Soluble.	
and Barium	Soluble.			
Protonitrate of	Soluble.			
Pernitrate of	Soluble.			
Protosulphate of	Soluble.			
Persulphate of	Very soluble,		Very soluble, also in Ether.	
POTASSA.				
Acetate of	100,			200
Ammonia-oxalate of	Soluble.			
Ammonia-sulphate of	13.			
Ammonia-tartrate of	Very soluble.			
Antimoniate of	Slightly.			
Antimonite of	Soluble.			
Arseniate of	Uncrystallizable,		3·75.	
Binarseniate of	18·86 at 40°,		Insoluble.	
Arsenite of	Uncrystallizable.			
Benzoate of	Very soluble.			
Bibenzoate of	10.			
Borate of	Soluble.			
Camphorate of	1,	25		
Carbonate of	100.			
Bicarbonate of	25,	83		
Chlorate of	6·03,	60 at 188½°		
Chromate	48,	extremely.	Insoluble.	
Bichromate of	10,	much more.		
Citrate of	Very soluble.			
Columbate of	Uncrystallizable.			
Ferrocyanide of	33·3,	100		
Iodide of Potassium	143 at 65° (*G. Lussac*).		Sparingly.	
Iodate of	7·14 (*Brande*).			
Molybdate of	Soluble.			
Chloride of Potassium	29·21 at 66·83° 59·26 at 229·28°		2·083 4·62 at 80° S. gr. of Sprts. ·900 1·66 ·812 0·38 ·834	
Nitrate of	29·31 at 64° 236·45 at 207° 285· at 238°			2·083
Oxalate of	50 (*Ure*), 30 (*Brande*),		2·76 at 80° Sp. gr. ·900 1 of Sprts. ·872	
Binoxalate of	(10 *Brande*.)	(*Ure* 100.)		
Quadroxalate of		66·66		2·91
Phosphate of	Difficultly soluble.			
Diphosphate of	Soluble in hot water.			
Biphosphate of	Very soluble.			
Hypophosphite of	Very deliquescent,		Very soluble.	
Hyposulphate of	Difficultly soluble at 60°, readily at 212°.			
Hyposulphite of	Deliquescent.			
and Silver	Difficultly.			
Succinate of	Very soluble.			
Sulphate of	10·57 at 54°. 26 33 at 214°.			
Bisulphate of	50 at 40°. 200 at 220°.			

Name of Salt.	Solubility in 100 parts Water		Solubility in 100 parts Alcohol	
	at 60°	at Boiling-point.	at 60°	at Boiling-point.
POTASSA.				
Sulphite of	100.			
Tartrate of	100,			0·416
Bitartrate of	1·05,	6·66		2·91
Tartrovinate of	10,	any quantity.		
Tungstate of	Uncrystallizable.			
Nitro-tungstate of		(*Ure*), 5		
SILVER.				
Acetate of	Very difficultly soluble.			
Arseniate of	Insoluble.			
Arsenite of	Insoluble.			
Borate of	Difficultly soluble.			
Chlorate of	25 (*Cheneviz*).			
Chromate of	Very slightly.			
Citrate of	Insoluble.			
Molybdate of	Insoluble.			
Chloride of (Fused)	Insoluble.			
Nitrate of (Cryst.)	100,	200		25
Oxalate of	Insoluble.			
Phosphate of	Insoluble.			
Succinate of	Soluble.			
Sulphate of	1·15.			
Sulphite of	Very little soluble.			
Hyposulphite of	Soluble.			
and Potassa	Difficultly soluble.			
Tartrate of	Soluble.			
and Potassa	Soluble.			
SODA.				
Acetate of	35,	150		
Arseniate of	10 (*Thompson*). 25 (*Ure*).			
Binarseniate of	Soluble.			
and Potassa	Soluble.			
Benzoate of	Very soluble.			
Biborate of	8·033,	50		
Carbonate of	50,	100		
Bicarbonate of	7·6.			
Chlorate of	33·3,		Sol. in sp. rect.	
Chromate of	Very soluble,		Sparingly.	
Citrate of	100 or more (*Brande*).			
Iodide of Sodium	173.			
Iodate of	7·3,		Insoluble.	
Molybdate of	Soluble.			
Muriate of (or Chloride of Sodium,	Equally soluble at all temperatures. (*Berz.*)		5·8 at 80° Sp.gr. of Spts.	·900
			3·6	·872
			0·5	·834
Nitrate of	33·3 at 60°	*Dumas.*		
	100 at 123°			
	50 at 60°	*Berzel.*		·958
	73 at 32°	(*Gay Lussac*).	10·5 at 80° Sp.gr. of Spts.	·900
	173 at 212°		6	·872
	80 at 32°	*Marx.*	0·38	·834
	22·7 at 50°			
	55 at 61°			
	218·5 at 246°			
Oxalate of	Sparingly soluble.			
Phosphate of	25,	50		
and Ammonia	Soluble.			
Biphosphate of	Very soluble.			

Name of Salt.	Solubility in 100 parts Water		Solubility in 100 parts Alcohol	
	at 60°	at Boiling-point.	at 60°	at Boiling-point.
SODA.				
Hypophosphite of	Very soluble,		Very soluble.	
Succinate of	Soluble.			
Sulphate of (Cryst.)	48·28 at 64°. 322·12 at 91°.			
Sulphate of (dry)	16·73 at 64° 50·65 at 91° 42·65 at 217°	(*Gay Lussac*).	Insoluble.	
Hyposulphate of	41·6,	91	Insoluble.	
Bisulphate of	50.			
Sulphate of, and Ammonia	Soluble.			
Sulphite of	25.			
Hyposulphite of	Deliquescent.		Insoluble.	
Tartrate of	56·37 (*Thomson*),		Insoluble.	
and Potassa	20.			
Tartrovinate of	Soluble,		Sol. in sp. rect., but sparingly in absolute alcohol.	
Tungstate of	25,	50		
STRONTIA.				
	0·625 at 60° 5 at 212°	(*Ure*).		
Hydrate of	2	50		
Acetate of	Very soluble.			
Arseniate of	Sparingly soluble.			
Arsenite of	Sparingly soluble.			
Borate of	0·76.			
Carbonate of	0·0651 at 212°.			
Chlorate of	Very soluble.		Soluble.	
Chloride of Strontium	50,		Soluble.	
Chromate of	Insoluble (*Brande*).			
Citrate of	Soluble.			
Ferrocyanuret of	25.			
Iodide of Strontium	Soluble.			
Iodate of	25.			
Nitrate of		113		
Oxalate of		0·52		
Phosphate of	Insoluble.			
Phosphite of	Soluble.			
Hypophosphite of	Very soluble.			
Succinate of	Soluble.			
Sulphate of	0·026 at 212°.			
Hyposulphite of	20 (*Gay Lussac*),		Insoluble.	
Hyposulphate of	22·22	66·66		
Tartrate of	0·67 at 170°.			
TIN.				
Acetate of	Soluble.			
Arseniate of	Insoluble.			
Borate of	Insoluble.			
Nitrate Proto. of	Uncrystallizable.			
Nitrate Per. of	Scarcely.			
Oxalate of	Soluble.			
Phosphate of	Insoluble.			
Succinate of	Soluble.			
Sulphate Proto. of	Crystallizable.			
Sulphate Per. of	Uncrystallizable.			
Tartrate of	Soluble.			
and Potassa	Very soluble.			

Name of Salt.	Solubility in 100 parts Water		Solubility in 100 parts Alcohol	
	at 60°	at Boiling-point.	at 60°	at Boiling-point.
ZINC.				
Acetate of	Very soluble.			
Antimoniate of	Very sparingly.			
Borate of	Insoluble.			
Chromate of	Sparingly.			
Citrate of	Scarcely.			
Chlorate of	Very soluble.			
Chloride of	Very soluble.		100 at 54½°.	
Iodide of	Soluble.			
Iodate of	Difficultly soluble.			
Lactate of	2 (*Ure*).			
Nitrate of	Deliquescent.			
Molybdate of	Insoluble.			
Oxalate of	Nearly insoluble.			
Phosphate of	Uncrystallizable.			
Succinate of	Soluble.			
Sulphate of	140 (*Dumas*).			
Sulphite of	81·81 at 220°,		Insoluble.	
Hyposulphite of	Soluble,		Soluble.	
Sulphate of, and Nickel	33·33.			
Tartrate of	Difficultly soluble.			
Tartrovinate of	Soluble,		Sparingly soluble.	
Trisulphate of	Soluble.			
ACID.				
Arsenious				
Vitreous	1·78 (*Graham*),	9·68		
Opaque	2·9 (*Graham*),	11·47		
Benzoic	·50.			
Boracic	3·9,	33·3	20 at 176° (*Henry*).	
Citric	133·33,	200	Soluble.	
Gallic	5,	33·33		
Oxalic (Cryst.)	11·5.			
Succinate (Cryst.)	4,	33·33	74 at 176°.	
Tartaric	150 (*Brande*),	200	Soluble.	
Brucia	·1177,	0·2	Soluble.	
Cinchonia	Insoluble,	0·04	Partially soluble.	
Morphia	Nearly insoluble,	1		4
Quinia	Nearly insoluble,	0·5	Very soluble.	
Strychnia	0·04 (*Graham*),	0·15	5· sp. gr. of spts. (*Duflos*).	870
Camphor	0·229,		75 at 176°.	
Cane Sugar	200.			

CHAPTER XXI.

MACERATION—INFUSION—DECOCTION—DIGESTION—BOILING—DISPLACEMENT.

MACERATION.—The soaking or steeping of a substance in a liquid, at the ordinary temperature, is termed maceration. It is almost exclusively applicable to organic substances, being most frequently resorted to as a means of hastening and facilitating the after-solution of the extractive parts of hard, compact, or impervious wood, roots, stems, and leaves, by the more active methods of DISPLACEMENT or of EBULLITION. It is employed when the soluble principles are alterable by heat; and is also made use of to effect the solution of a substance containing several principles, the solubility of which varies with the temperature applied, as it leaves those which are not taken up in the cold to be acted upon by the aid of heat in a subsequent operation. Thus, for example, in the treatment of most vegetable substances, starch, which is generally present and is only soluble at the boiling-point of water, will remain untouched, while all other principles soluble without heat can be separated from it.

The mode of performing the process is merely to place together, in a vessel, the solvent and the substance to be dissolved, and to allow them to remain a longer or shorter time, according to the nature of the substance. For ordinary purposes, a loosely covered pan of blue stoneware is very convenient. In delicate operations, a beaker-glass, Fig. 340, or solution jar, Fig. 343, is more appropriate. When the solvent is volatile, a wide-mouthed stoppered bottle may be used.

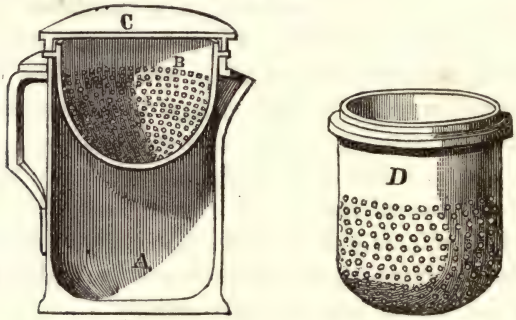
Fig. 343.

INFUSION.—This process is likewise applicable almost solely to organic substances. Instead, however, of the solid remaining in contact for a length of time with the solvent, the latter is first heated to boiling and then poured upon the former. After having cooled, the liquid may be decanted or pressed out.

This mode is used for the exhaustion of flowers, leaves, roots, seeds, and other substances of delicate texture, which are easily penetrable and readily yield their soluble matters; and especially for the purpose of extracting volatile ingredients. The heat applied to the solvent increases its energy; but as the material is only in contact for a limited time, the interval between the commencement and completion of the operation is not sufficient to affect the material or solution, even though one or more of its components are alterable by heat.

For small operations, a beaker glass covered with a capsule, or a yellow earthenware stew-pan with lip and cover, such as can be had at the crockery shops, are admirably adapted. In larger pharmaceutical processes, a special apparatus, Fig. 344, is em-

Fig. 344.



ployed. It is known as Alsop and Squire's Infusion Pot, and consists of three pieces, an outer pitcher form vessel A, an inner perforated bowl B, and a cover C. Its material is generally white stoneware or porcelain, but it may also be made of metal. The inner bowl serves as a support for the solid matters to be infused, and retains them, during the treatment, in constant contact with the liquor in the outer vessel. After the action is completed, it is only necessary to remove the cover and lift out the cullendered bowl; for the infusion is clear and ready for use without the necessity of filtration.

Decoction.—This mode of solution, which is so important to the Pharmaceutist, is chiefly employed for the purpose of exhausting those vegetable substances, which will not readily yield their soluble matters to water. It is merely an extension of the

last process, and consists in boiling the material to be dissolved with a hot solvent in a covered vessel, or saucepan, until all soluble matter is taken up. Most volatile matters are expelled by decoction; but those which are insoluble, save by prolonged action of heat, are dissolved or suspended, as it were, by favor of other principles present.

Decoction is only used with liquid solvents which are not decomposable by heat.

In all of the preceding processes, as well also in others in which solid vegetable matter is subjected to the solvent action of liquids, the cullendered ladle, Fig. 345, of tinned wire, is most

Fig. 345.

useful for transferring the residue to the press, for removal of any retained liquid.

Digestion.—This mode of solution differs from maceration in requiring the assistance of heat, and consists in exposing a body to the prolonged action of a liquid in a covered vessel, at any temperature between 90° F. and several degrees less than the boiling-point of the solvent. The method of heating varies with circumstances, and can be, by a gentle fire, or by the sand, steam, water, or saline *Bath*, as the nature of the operation may require.

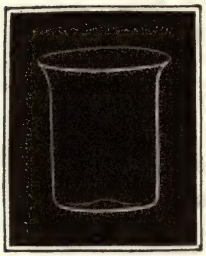
In analysis, glass or platinum vessels are used; but in less important operations, those of other materials are more convenient and economical.

A very important advantage of digestion is, that it allows the perfect solution of all soluble portions of a substance, without modifying the nature of the solvent. It is especially useful for the decomposition of ores, minerals, and other substances difficultly acted upon by acids or other solvents, and also for effecting the synthesis of compounds requiring a long-continued heat. Moreover, it is very available in preparing alcoholic and aqueous solutions, medicinal oils, and other pharmaceutical products.

In analytic operations, digestion is performed in beaker glasses.

These are bell-shaped vessels, Fig. 346, of Bohemian glass, and uniformly thin throughout, so as to support a considerable elevation of temperature. The glass must be well annealed, hard, and free from lead, so as to resist the action of acids. These vessels come in nests of different numbers. Their size varies gradually upwards from an ounce in capacity to a gallon.

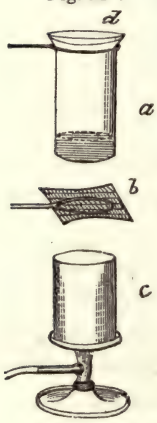
Fig. 346.



The substance to be acted upon, in a state of fine powder, is transferred to the glass, which must be perfectly clean, and is then mixed with the proper quantity of acid or other liquid by shaking the glass after the addition, or by the use of a glass stirrer, taking care, however, in this last instance, if for analysis, to wash off adhering particles previous to its withdrawal, with a little fresh solvent. The glass is then to be covered with a square of window-glass (free from lead), a porcelain capsule, or watch-glass, whichever is most convenient, so that the volatilized vapors condensing upon its bottom may fall back again into the vessel.

If the glass is small, it may be directly heated over the lowered flame of a gas or spirit-lamp, Figs. 40, 41, cautiously and gradually heightened as the glass becomes heated. To modify the action of the flame and diminish the danger of fracture of the glass, a fine wire gauze *b*, for the diffusion of the heat, may be interposed between its bottom and the flame. Fig. 347 represents a digestion in a beaker glass *a*, over a gas lamp *c*. For larger vessels a SAND-BATH must be used.

Fig. 347.



Thin flat-bottomed flasks, with narrow necks and smooth tops, Fig. 348, made of hard glass, free from lead, are sold especially for this purpose; but the common sweet oil or Florence flasks are much more economical and equally convenient for operations adapted to their capacity.

When it is important that not even a drop of substance shall be lost, as in analytic operations, the digesting flask should have the form shown in Fig. 349. The body is pear-shaped, with a flat

Fig. 348.

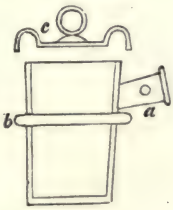
Fig. 349.

bottom, and gradually tapers towards the mouth, which is lipped to facilitate the pouring of the contents.

Digestion on a small scale with inflammable liquids, must always be effected by the sand-bath, so as to avoid danger of explosion from ignition of vaporized particles. The sand-bath may then be heated over the lamp, as at Fig. 155; and in large operations by the small charcoal furnace, as at Fig. 124.

A digestion apparatus, of Berlin porcelain, adapted for a water-bath, is shown in Fig. 350. Its dimensions are 7 inches in height, and 4 inches in diameter, the capacity being about 40 ounces. The projection *b* is a flange for its support in the bath; *a*, the socket for a wooden handle, and *c*, a section of the cover. These vessels, made also of other sizes, are very convenient in pharmaceutical operations, for the digestion of organic matters, especially those of vegetable origin.

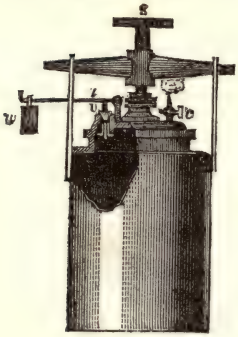
Fig. 350.



Digestion under Pressure.—The solvent power of water may be greatly increased by presenting it to the substance in the state of vapor. This property affords the advantage of making aqueous solutions of highly obstinate substances. The appropriate apparatus is termed a digester. That which Papin used for exhausting bones of their gelatin, Fig. 351, consisted of a strong, cylindrical, iron or copper vessel, with sides sufficiently thick to resist

a considerable degree of pressure. The cover, made to fit closely to the body, is fastened down by a screw *s*. There are two openings in it, one for the stop-cock *c*, and the other for the safety-valve *v*, with its weight *l w*, by which it can be loaded so as to resist a pressure within of 40 to 50 atmospheres, if necessary. The arrangement of the valve is shown in the broken part of the drawing. The steam accumulating in the upper part of the body, when matters are under treatment, being confined by the loaded valve and unable to escape, exerts a great pressure upon the liquid mixture beneath, and thus allows it to be raised to a very high degree of heat without boiling. The stop-cock *c* is convenient as a try-cock, for making examinations during the progress of the experiments. The lever regulates the pressure in proportion to the weight placed upon it.

Fig. 351.



In large operations, D'Arcet's apparatus (see *Encyclopædia of Chemistry*, article GELATIN) is much used. It is shown in Figs. 352 and 353. Our description refers to the extraction of gelatin from bones by water in a state of tense vaporization.

Fig. 352.

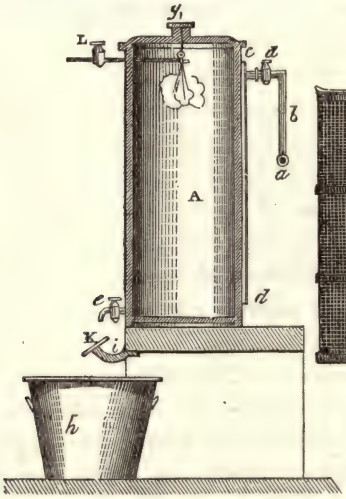


Fig. 353.

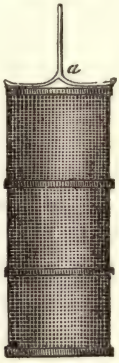


Fig. 352 is a vertical section of the apparatus. A is an hermetically closed cast-iron cylinder, into which the steam is conducted; *a* the main steam-pipe; *b* a vertical pipe conveying the steam into the cylinder A; *c c* branch-pipes leading the steam to the bottom of the cylinder; *d* a stop-cock upon the pipe *b*, for regulating the entrance of the steam into the interior of the cylinder. (The tubes and the cylinder should be wrapped around with woollens, so as to retain their heat and prevent their cooling.) *e* is the stop-cock for the discharge of the gelatinous solution; *f* the cover of the cylinder, which is fastened to the cylinder, so as to prevent the escape of any of its contents; *g* a tubulure in the cover for the reception of a thermometer; *h* a tub to receive the solution as it is formed; *i* a gutter for conveying into another vessel the grease which is run off in the commencement of the operation; K another gutter, moving on a pivot, which receives the liquid as it runs from the cock *e*, and empties it into the tub *h*, or into the trench *i*; *l* a tube for feeding the interior of the cylinder with fresh water; *m* a movable adjustment attached to the pipe *l* for regulating the quantity of water and preventing a too great elevation of temperature in the interior of the apparatus.

Fig. 353, elevation of the interior basket, made of wire-cloth. This basket, or cage, receives the cleansed and crushed bones, and is enclosed in the cylinder A; *a* is the handle with which, by means of a pulley, it is lifted or lowered, to be emptied or charged. Four or more of these machines make a series, and the boiler which feeds them with steam should carry a pressure of 4 lbs. to the inch.

When volatile or costly liquids are used as solvents in digesting processes, it is necessary, both on the score of economy and of the efficacy of the process, to use certain precautions. In making pharmaceutical preparations with alcohol or ether, for example, it must be remembered that these liquids volatilize by a high heat, and unless the vaporized particles are by a suitable arrangement condensed and returned to renew action upon the substance, the latter will be evaporated to dryness long before sufficient time has elapsed for the completion of its solution. For this purpose an ordinary cooling-worm may be attached, as shown in Fig. 354. The vapors escaping from the digesting vessel *a*,

are condensed partly in the inclined tube *b*, and partly in the worm C, and fall back again into the flask as soon as they become liquefied by the water surrounding the worm. This arrangement allows a prolonged contact of solids and volatile liquids, without loss or alteration of the latter,—a very important consideration, as time is an influential adjunct in digestion.

Fig. 354.

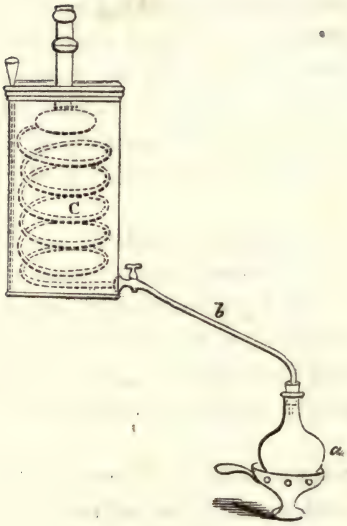
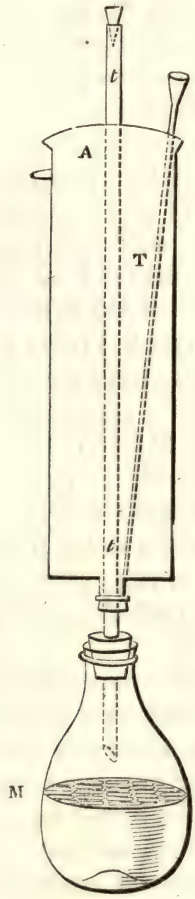


Fig. 355.



Mohr improves upon the above apparatus, by giving it the form exhibited in Fig. 355. It consists of a tin plate cylinder A, tubulated at its bottom. Through this tubulure passes a glass

tube *t t*, adjusted by perforated corks to the tubulures of both cylinder and digesting vessel M. The vaporized matter, ascending from the heating vessel M, is cooled by the water in the cylinder, and which surrounds the tube *t t*. The long-barrelled, tin plate funnel T, receives the amount of water freshly added, and conveys it to the bottom to displace that which has become heated, and which by its less density rises to make its escape through the outlet A.

SOLUTION BY BOILING.—This mode is resorted to when a substance can only be exhausted of its soluble portion at the boiling-point of the solvent. The exact point of temperature at which a liquid boils, depends partly upon the amount and fluctuations of pressure, and the nature and construction of the vessel. When the pressure of supernatant vapor is removed by uncovering the vessel, ebullition is facilitated and takes place at lower temperatures. Indentation or roughening of the surface of the heating vessel, or any other means by which the heating surface is increased, and escape of gaseous matter is promoted, lowers the boiling-point of a liquid. For this latter reason, platinum scraps or pieces of unglazed card, or of cork, pacify turbulent ebullition and render the process tranquil and uniform.

The heat applied should never exceed the degree at which the solvent boils, especially in metallic vessels, otherwise ebullition is retarded, for beyond a certain temperature a repulsion between the particles of liquid and the metallic surfaces prevents direct contact.

The kind of apparatus varies with the nature and quantity of material under process.

Boiling in Tubes.—Test-tubes, Fig. 356, are very convenient implements for delicate solutions, assays, and the like, and, therefore, the laboratory should be supplied with a large assortment, varying from three inches in length and a quarter inch in diameter to six inches in length and one inch in diameter. They should be of hard, white German glass, free from lead, with perfectly round bottoms, uniformly thin, so as to withstand heat. The rack, Fig. 39, serves as their support.

A test-tube should never be charged with more than one-third its capacity of solvent, else there may be loss by ejection from too sudden ebullition; and the solid substance, previously pow-

dered, is not to be added until the liquid is brought to boiling, and then only in small portions at a time.

To guard against spirting, and to insure a uniform heating, the tube must be gradually heated, not upon its bottom, but near to

Fig. 356.

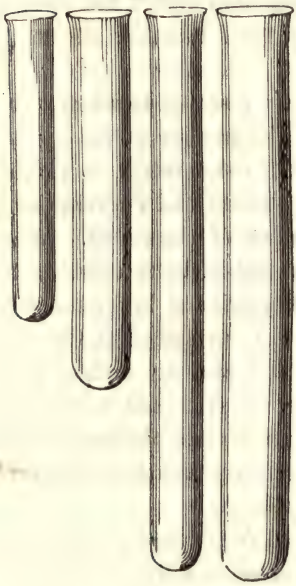
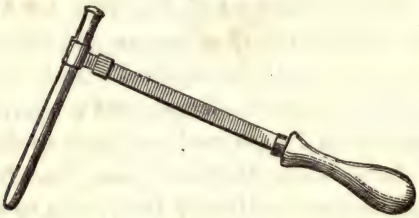


Fig. 357.

or on the side, as shown in Fig. 357. It is, as seen, heated over a small lamp, being held in the fingers, which are protected from contact with the hot glass by a doubled strip of thick

Fig. 358.



paper wrapped around the neck of the tube for its support. The spring holder, Fig. 358, consisting of a wooden handle affixed to two flat pieces of sheet-brass, indented at their ends so as to

form a round catch, and tightened or loosened by a slide, would be much more convenient for the purpose.

The mouth of the tube during heating, or whilst its contents are being shaken, should always be held away from the operator, else ejected matter may endanger his person or dress.

Faraday gives the following valuable advice as to the use of test-tubes for making solutions with volatile liquids, and under pressure.

"In consequence of the small diameter, and therefore small sectional area of tubes, they are much stronger relatively to internal pressure than larger vessels, such as flasks of the same thickness. An advantage is thus gained in some cases of solution or digestion in certain fluids, as alcohol, ether, and even water, because it enables the experimenter to subject the substances to temperatures as high as the boiling-points without loss of the fluid, or occasionally to temperatures still higher, the ebullition going on as it were under pressure. This is easily performed with alcohol, ether, and similarly volatile fluids, in tubes of four, five, or six inches in length, and of such diameter as to be readily and perfectly closed by the finger. Suppose a tube of this kind, one-third filled with alcohol, and held tightly between the thumb and second finger of the right hand, its orifice being closed by the forefinger of the same hand, Fig. 339. The forefinger is to be relaxed, and the heat of a spirit-lamp applied until the alcohol begins to boil; the forefinger is then to be reapplied closely, and it will be found that the flame of the lamp, applied at intervals, is quite sufficient to keep the temperature up to the boiling-point. No alcohol can evaporate, for the finger has power sufficient to retain the vapor even were its force equal to two atmospheres, and the tube itself is also strong enough to resist the same force.

"This operation is very advantageous when valuable and volatile solvents are in use; it is therefore worth while to refer to those points which indicate the state and temperature of the fluid, and which make the practice easy. If the fluid be one which, like alcohol, when at or above its boiling-point is at a temperature inconvenient to the hand, then, if all the common air were allowed to pass out of the tube before closing it, the whole tube would become heated by the vapor rising from the

hot liquid beneath, and the fingers would be injured; but by not allowing all the air to escape, that portion which is retained in the tube is always forced to the top by the successive formation and condensation of the vapor below, and interfering with the passage of the hot vapor to the part which it occupies, it preserves that portion of the tube at comparatively low and very bearable temperatures. The part thus retained at a low temperature is proportionate to the quantity of air confined in the tube; this quantity is usually a proper one if the tube be closed just after the alcohol has begun to boil, and before the upper part of the tube has been heated. If too much air has been expelled, and the tube is found to become hot above, the application of the flame must be suspended a moment or two, the whole suffered to cool below the boiling-point, the tube opened, the upper part cooled slightly by a piece of moist paper or a cold finger, and then the forefinger is to be reapplied to close it as before.

"The state of the fluid within is in part indicated by the pressure of the air or vapor on the finger, the latter being urged away from the tube by a force proportionate to the degree of heat above the boiling-point, and being drawn inwards when the heat is below that point. Generally, therefore, the finger alone will serve to ascertain whether the temperature is above or below the point of ebullition; but as the force required is, after operating for some time at high pressures, such as to diminish the sensibility of the finger to smaller pressures, it sometimes happens that, on lowering the temperature, the period at which it attains that of ebullition in the atmosphere cannot be distinguished. This point is, however, easily recognized by relieving the pressure of the finger slightly; should the quiescent fluid below then burst into ebullition, it is a proof that its temperature is higher than the boiling-point at atmospheric pressure, but should it remain quiescent until the finger is entirely removed, its temperature will be known to be below that point."

Boiling in Beaker Glasses and Flasks.—These vessels are used when large quantities of liquid are to be operated upon. When the direct heat of the lamp is applied, it should be diffused by the intervention of a wire gauze. The preferable mode of heating is by a highly heated sand-bath. The same remarks as to their material and construction, as given before at p. 271, are

applicable in this instance. They should be loosely covered during the operation, the beaker glasses with capsules, and the mouths of the flasks with watch-glasses. The position of the beaker glass over the lamp is shown at Fig. 347, that of flasks at Fig. 155. Round-bottomed flasks, Figs. 359, 360, 361, are

Fig. 359.

Fig. 360.

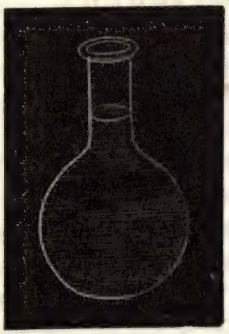
Fig. 361.

Fig. 362.

made of different sizes, especially for solutions; but Florence flasks, Fig. 362, which have been rounded on the edges of the mouth over the blowpipe flame, so as to allow the easy entrance of a loose cork, are equally convenient and less costly. They are thin and uniform throughout, and bear very high temperatures without fracture. Annexed are drawings, also, of two wide-mouth boiling flasks, which, like the above, have round bottoms.

Fig. 363.

Fig. 364.



Boiling in Capsules.—Solution is made in open vessels when the solvent liquid is not easily vaporizable or alterable by expo-

sure, or when its loss is of little consequence. The most convenient implements for the purpose are porcelain capsules, Figs. 365, 366. Those from the French and Royal Prussian factories

Fig. 365.

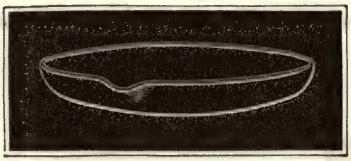


Fig. 366.

are far superior to those of any other make. They are strong, yet uniformly thin throughout, and support very high temperatures and sudden changes. Being enamelled, they are protected from the action of acids or corrosive liquids, and consequently are of general application. They are sold of all sizes, varying upwards from an ounce to 18 oz. in capacity. The diameter of the smallest is about two inches, and that of the largest 15½ inches. The depth should be one-third of the diameter. The smaller sizes come in nests of a half dozen or more. Fig. 365 represents one with spreading rim and lip to facilitate pouring. That shown in Fig. 366 has a more hemispherical shape.

Capsules are almost always heated over the open fire, the spirit or gas lamp furnishing the requisite temperature. Those of smaller size are shown in position upon suitable supports at Fig. 154, and *i*, Fig. 155; and for the larger, Luhmé's lamp, Fig. 158, answers an admirable purpose.

The liquid is placed in the capsule before the ignition of the wick, and when it is boiling, the substance to be acted on should be gradually deposited in it in a finely divided state, during constant stirring with a glass rod. After all has been added, both ebullition and stirring must be continued until the completion of the process, care being taken to supply the loss of the volatilized portion by fresh additions of the solvents, unless the solution is to be evaporated.

When the nature of the materials requires the intervention of a medium other than sand to modify the heat, a rare occurrence when operating in capsules, the latter are heated over baths, as shown at Fig. 200. Capsules or boiling pans of enamelled ironware or tinned copper are used only in very large operations.

Solution by Steam.—When a substance is to be dissolved

by steam heat, and the nature of the materials renders the direct application of steam inadmissible, then baths, Fig. 18, come very appropriately into play.

For aqueous solutions which are greatly facilitated by the immediate action of steam, it is supplied through flexible lead tubes, leading from the generator, Fig. 15, directly into the containing vessel.

For small operations in glass vessels, the copper spritz, Fig. 240, half filled with water, and heated over the gas lamp, readily furnishes sufficient steam.

As boiling by steam is practised in numerous chemical operations, it is proper to introduce some directions pertinent to the subject.

It is very seldom that the heat required for ordinary laboratory purposes exceeds that given by five pounds, or at furthest fifteen pounds, above atmospheric pressure, and the fire under the generator and weights upon the safety valve should be regulated accordingly.

If the mixture to be boiled is unalterable by the action of condensed steam, the conduit-pipe may lead directly into it, and to the bottom.

As the liquid appears to boil before it actually does, the only sure indication of temperature is to be obtained by a thermometer, Fig. 119.

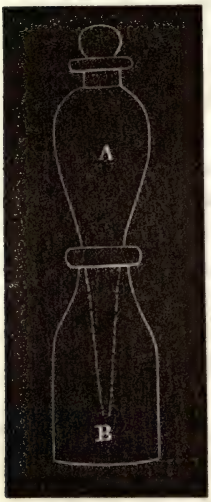
This method, however, causes a great loss of heat and incommodes the operator, by filling the apartment with clouds of vapor. A *loose* cover will partially remove these objections. In boiling in this way, care must be taken that the fire does not get low, lest a condensation of the vapor occupying the upper part of the boiler causes a partial vacuum, and the consequent drawing over of part of the liquid from the vat into the boiler. The conduit connected with the feeder should always have a stop-cock near the coupling, which is to be shut off upon the completion of the operation. If the boiler should then happen to be surcharged with steam, it must be blown off through the valve, this being readily accomplished by gradually unloading the lever.

A far better plan of boiling by steam is to conduct it through a coil of pipe placed at the bottom of the vat, and having an exhausting-pipe leading into the neighboring flue. This mode

allows a uniform temperature at any degree, upwards, from that of the atmosphere—suitable stop-cocks being attached for that purpose to regulate the supply of steam accordingly.

In cold weather, and especially when the feeder or conduit are of any length, it will be economical to wrap them with woollen listings or straw, as means of preventing condensation.

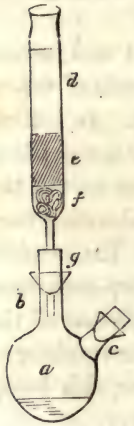
Fig. 367.



SOLUTION BY DISPLACEMENT.—Displacement, termed also lixiviation, when applied to the solution of saline substances, is an economical, speedy, and efficient means for the extraction of the soluble portions of woods, leaves, flowers, barks, precipitates, and similar matters, by the infiltration of a liquid solvent through them. This process is equally applicable for maceration, infusion, and decoction; for though operating in the cold, it accomplishes its purpose.

For delicate operations, and those conducted upon a scale of moderate extent, glass vessels may be employed. One of the usual form is shown in Fig. 367. It is made of hard glass, free from lead, the upper part, or A, being the displacer, and the lower part, B, an ordinary flask, the recipient of the saturated solution. The mouth of the bottle and that portion of the displacer which rests in it should be ground so as to make a close joint. The stopple is for closing the upper vessel when necessary. Dobereiner's modification of the above, but operating upon the same principle, is shown in Fig. 368. To prevent the passage of the material through the barrel of the displacer, it must be loosely closed with a plug of raw cotton as at *f*, and then adjusted by means of a perforated cork *g*, with the vertical tubulure of the globular receiver *a*. The whole apparatus as adjusted is retained in an upright position by a support, the receiver resting upon a braided straw ring. It is then ready to receive its charge. The substance in coarse powder and moistened, occupies the part of the vessel *e*,

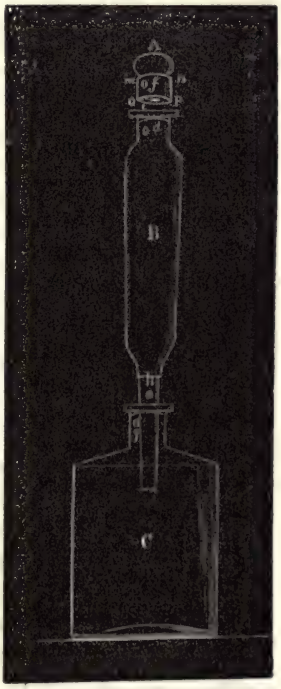
Fig. 368.



and the solvent is subsequently added as at *d*. A partial vacuum being made in the receiver by the evaporation of a few drops of alcohol added through the lateral stoppered tubulure *c*, the liquid percolates through the solid mass by the force of atmospheric pressure, and ultimately reaches the receiver saturated with the soluble matter of the material *e*.

In order to express clearly the rationale of this process, we will suppose that vegetable matter, a dye-wood for example, in coarse powder, is to undergo exhaustion by this method. It occupies the part *e*, as before said, and to facilitate the percolation, has been previously moistened with a portion of the solvent. If the substance swells easily it must be packed lightly. Liquid is added, as shown at *d*, and soon soaks into the mass beneath; another portion of the solvent is then poured in as before, and takes the same course, displacing the portion before used without mixing with it. These strata of solvent are pressed downwards by successive additions of liquid, and become more and more charged with soluble matter, as they approach the bottom of the mass, until at last they run out into the recipient highly charged, and, in the present instance, highly-colored;—the first runnings being more nearly saturated than those which follow. When by consecutive additions of solvent the material has become exhausted, the liquid passes through the mass and reaches the receiver as tasteless and uncolored as when first poured in. This indicates the completion of the process.

Fig. 369.



Robiquet's displacer, which differs somewhat from the preceding, is shown by the annexed drawing, Fig. 369. It consists of a barrel B, a ground glass stopper A, and a receiving bottle C.

The body, *m n o p*, of the stopper is hollow, and pierced with

a hole *f*, of about one-tenth of an inch diameter. There are corresponding holes also in its bottom *e*, as well as at *d* and *h* of the barrel, and *g* of the receiver.

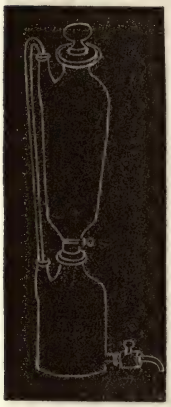
When the stopper is placed in the mouth of the barrel, so that the two holes *f* and *d* come together, there is still a communication between the external air and the interior of the barrel, which is further established by bringing the two other openings *g* and *h* into coincidence.

It will be readily seen, therefore, that the internal pressure of the air, and the flow of the percolating liquid, can be regulated at pleasure, merely by turning the barrel more or less, so as to shut or close the opening as may be desired.

The neck of a retort, with its smaller end adjusted to a wide-mouth bottle by means of a perforated cork, makes an excellent displacing apparatus.

When the solvent is volatile, in order to prevent loss by evaporation, the apparatus must have a modified form, as shown in Fig. 370. The displacer is adapted to the centre tubulure of a two-necked Wolffe bottle. As atmospheric pressure is an important agent of this process, it will not do to shut it off by closing the top of the displacer without making some compensating arrangement, and, therefore, a communication between the upper and lower vessel is established by means of a bent tube adjusted in the lateral tubulure of each. In this manner the vessel is completely closed, and vaporization prevented, while the pressure produced is distributed throughout the vessel, and thus rendered uniform. In using the glass displacement apparatus first described, this principle must be recollected; where a vacuum is not artificially created in the receiver, the ground glass edges of it and the displacer should either be permanently separated or occasionally disjointed.

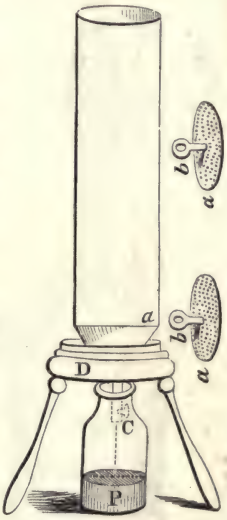
Fig. 370.



The stop-cock near the bottom of the receiver allows the withdrawal of the solution as fast as it accumulates, without the necessity of disarranging the apparatus. In experiments upon large quantities of material, and in pharmaceutical operations

generally, the displacers employed are made of tinned copper or tinned plate. Those of porcelain, which are now in the market, are much more serviceable, because they are readily cleansed and resist the action of corrosive liquids. Of whatever material they are made, they should be cylindrical and funnel-shaped at the base, and the height should be at least four times the diameter, as is shown in Fig. 371. At *a* there is a flange in the interior as a support for the cullendered diaphragm *a b*. These diaphragms are removable, and for convenience in handling have a knob in the centre. The lower diaphragm is always to be covered with a circle of coarse muslin, for the reception of the material, and to prevent the passage of particles as well as obstruction of the holes. The other diaphragm, fitting loosely to the cylinder, rests upon the top of the powder, and serves for the better distribution of the solvent and for the prevention of the escape of dusty particles, which sometimes occurs if the powder is put in dry. The stop-cock C in the barrel or exit-pipe is useful for regulating the discharge of the liquid.

Fig. 371.

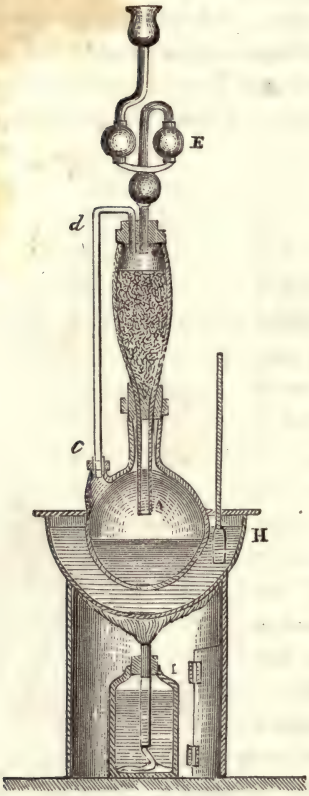


The tripod D is the support, and allows the withdrawal of the receiver P, when it is full, and when it is to be replaced by another, without the necessity of disturbing the displacer.

Payen's is another very convenient form of displacer, in which ether, alcohol, and any other volatile solvent may be kept in constant action without exposure to air or loss by evaporation. By its use a great saving of time and labor and solvent is gained. The arrangement is exhibited at Fig. 372. It consists of a glass cylinder B, the funnel of which should reach to the centre of a glass balloon A, beneath the two vessels, being attached by means of a perforated cork. The lateral tube *c*, *d*, opens communication between the lower and upper apartments. As the whole forms a perfectly tight connection, the safety-tube E becomes necessary for the regulation of the dilatation and contraction of the vapors.

When it is desired to exhaust a vegetable matter with alcohol or ether, and at one and the same operation to concentrate the charged solvent, plug the barrel of B with raw cotton, previously moistened with the liquid to be used; add the powdered material, cover it with a cullendered disk, pour on the liquid in quantity sufficient to give a filtered solution of half the capacity of the balloon, and then connect the apparatus. The balloon is now to be placed half its depth in the water-bath H, and the apparatus sustained in a perpendicular position by means of a clamp support. The water-bath is to be closed with a loose cover, and heated as may be required by the small spirit-lamp I. The ether or alcohol which has infiltrated into the balloon thus carried to, and maintained at ebullition, passes off as vapor into the lateral tube, there partially condenses and falls upon the material in the cylinder to infiltrate through again. The excess of vapor and of expanded air escapes through the safety-tube; but a part of the vapor is arrested and condenses in the three bulbs, the first of which immediately empties its liquefied contents into the cylinder to renew its action upon the powder.

Fig. 372.



The concentration of the filtered solution is thus continually going on in the balloon, the concurrent distillation returning the evaporated particles to the substances to be exhausted, through the lateral tube *c*, *d*.

When water is the liquid to be employed, the water-bath must be replaced by a saline or sand-bath, and the spirit-lamp by a furnace.

For the solution of difficultly soluble substances, displacement presents many advantages, and amongst others it yields a clear solution, and supersedes the necessity of FILTRATION, which is required for most solutions made by infusion, decoction, and boiling. It is particularly applicable to the purpose of procuring concentrated solutions for EVAPORATION to extracts, as well as for making tinctures, &c.

The solvent may be acid, alkaline, spirituous, ethereal, or aqueous in its nature, the principle of its action being the same in all cases. When the liquid is corrosive, however, the vessel should not be metallic, but of glass or porcelain, and should be plugged with asbestos instead of cotton. It is immaterial whether the solvent be applied cold or warm, save when the process is resorted to for the separation of substances soluble in cold from those which are only soluble in hot liquids. Except in such cases, heat may be used, as it increases the power of the solvent; and a convenient means of applying it is to encompass the apparatus with a metallic jacket, and supply the intervening chamber thus formed with a current of steam from the generator, Fig. 16.

There are certain conditions necessary to the success of this operation. The material must be in powder of medium DIVISION; neither too fine nor too coarse, for in the first case it clogs the cloth and holes of the diaphragm, and, if heavy and compact, retards the percolation of the liquids. On the other hand, when too gross, the transit of the solvent is so rapid that the material is but partially acted upon. When alcohol or ether is used, the powder may be a little finer than for less volatile solvents; and all powders liable to *set*, or to become so compact as to prevent the passage of liquid, must previously be mixed with well-washed coarse white sand. This addition remedies the defect and insures the easy passage of the solvent.

The material, as before recommended, should be moistened with half its weight of the solvent, and left to soak for an hour or more before being placed in the percolator. After having been transferred, it is covered with the diaphragm, and sufficient liquid is poured upon it to cover entirely its surface. As soon as this first portion infiltrates through the mass, another portion is added; for it is only by keeping the surface covered with solvent that a uniform penetration of all portions of the mass can be

effected. If the liquid passes through very rapidly, the mass is too loose, and must therefore be compressed by pressing upon the diaphragm cover. Or, in order to prolong their contact, the stop-cock *c* may be nearly closed, so as to allow the exit of only a thin stream.

When alcohol or other valuable volatile liquid is used, the residual portions may be either extracted by pressure of the mass P, or by displacement with water; and subsequently, by distillation of the resulting mixture. The general practice, however, in the laboratory is to reserve the last running for the first application to fresh material.

CADET'S MODE OF SOLUTION.—This plan is well adapted to those powders which do not admit of being easily infiltrated. It consists in macerating or infusing the pulverized material with double its weight of cold or hot solvent, and after some time subjecting it to strong pressure. This treatment is to be repeated until the substance ceases to yield soluble matter, and the resulting liquids are then mixed together and filtered. Cadet's mode is used largely for dissolving the tannin from galls with ether.

A suitable press for this purpose is shown at Figs. 373 and 374. All powders which have undergone the process of solution

Fig. 373.

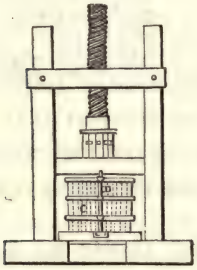
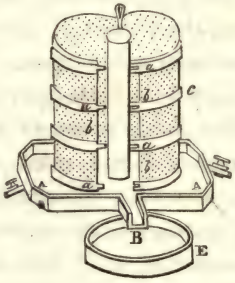


Fig. 374.



in large quantity should be subjected to its action, as a good deal of retained solution may thus be obtained, and consequently saved.

It is formed of two strong upright stanchions, and two proportionably strong cross-pieces, firmly jointed in the side-beams. The upper cross-piece carries a box through which works an ordi-

nary press screw, in the usual manner. Upon the lower cross-piece, is placed a wooden trough, A (Fig. 374), at least two inches deep, and to the front of which is adapted a gutter B, for the conveyance of the liquid, which assembles in the trough, to a vessel E, placed at and beneath its mouth. Upon and within the trough is placed a wrought-iron plate cylinder. This cylinder is formed of two semi-cylinders joined together. Throughout its height, it is divided off alternately into equal parts by zones or belts. The zones *a a* are more than an inch broad; the partition *b*, &c., four or five inches in width. The top as well as the lower zone is narrow. All the wider divisions are cullendered throughout their circumference with innumerable small holes, through which the liquid is to flow when pressure is applied. All the narrow zones are secured by a strong wrought-iron ring, formed of two pieces working on a hinge adjusted at the back. Upon the front is a movable broach D, which bolts them together, and makes the cylinder compact, so that it can resist the pressure applied. When the marc is exhausted, by draining out the broach D, the circumference of the cylinder is loosened or extended, so that its contents can be removed without difficulty. The marc is placed in this cylinder and pressed out by the power of the screw, until no more fluid will exude, even with the force of a man to the lever. The liquid runs into the gutter B and through a sieve, which should be properly placed for the purpose, into the vessel E, and may thence be drawn off after it has settled, into suitable vessels. The residual exhausted powder is, as said above, easily emptied out by loosening and removing the pin D.

A much more convenient implement than the preceding is the lever press, described in Muspratt's Chemistry, and a perspective view of which is shown by Fig. 375. It consists of two wrought-iron pillars B B, supported in sockets by the cast-iron feet A A. The bed-piece C is also secured to the feet by two perforated ears, and has two intersecting grooves sunk into its surface, as channels for conducting off the expressed liquid. The follower D, corresponding in size with the bed-piece C, is adjusted to the pillars by sliding-ears, and has the rack-bar F fixed in the centre. The gearing is sustained by framework E attached to B B. Motion is effected as follows:—The ratchet-wheel G turns upon an axle

having its bearings in the top frame. On the same centre is a fixed pinion of eight teeth, only partially seen in the figure, which

Fig. 375.

works in the wheel I, of twenty-four cogs; and upon the axis of I is another eight-teeth pinion, which acts upon the rack. The lever K is forked at the extremity nearest the small winch-handle L, and the terminations of the furcation are received upon the axle G. A pin, near H, is adapted to a small hole in the frame, by the insertion of which the descent of the lever may be prevented. The matter to be pressed is placed in a shallow, cylindrical box A, of tinned copper, Fig. 376, which rests upon the bed C of the press. To prevent the contents from being pressed against the sides of the cylinder, and thus obstructing the flow of the liquid thence, it is necessary to use a perforated band with perpendicular ribs on the exterior. Being movable and formed of two parts joined together by a hinge, it can be easily put in proper position around the matters to be pressed (after the latter has been placed in the box), and fastened by means of the pin. The ribs on the outer circumference of this band project against

Fig. 376.

the inner sides of the box, and form intermediate grooves, through which the expressed liquid, issuing from the holes, can readily pass off into the receiving vessel at the spout beneath.

To put the press in action, the lever being upheld by the pin at H, the winch-handle is turned to the left, in order to lower the rack and follower, until the latter presses upon the wooden block B, Fig. 376, which caps the material under pressure. The lever is then raised, and the pall allowed to work into the ratchet, which will cause the latter to turn, and produce the descent of the rack. This is repeated, if requisite, until a considerable pressure is obtained; and should it be desired to go on, the lever is elevated considerably above the horizontal line, and left to follow the consolidation of the contents of the bag. If, however, this is unnecessary, the pin H is inserted, upon which the lever remains. The amount of pressure is also regulated by the disposal of the weight M in the various notches of the lever.

When it is not expedient, as in the case of pulpy and similar matters, to press the substance in the box without first enveloping it in a cloth, it may be wrapped in unbleached Russia canvas; and the bag-shape bundles thus formed placed in the box, with a stiff plate of tinned copper interposing every two of them. They should be folded so as not to make a thickness of more than an inch.

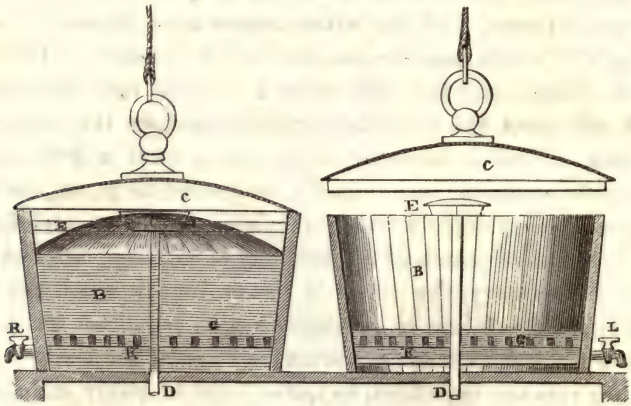
As the cloths absorb a considerable quantity of the expressed juice, and occasion loss, the pressing should be accomplished without them in all possible cases. The cloths, used for confining substances from which oily liquid is to be expressed, must be woollen and thick.

The pressure must be in all cases gradual at the commencement.

Solution under Pressure of Steam.—Figs. 377 and 378 exhibit Duvoir's bucking apparatus, which, as modified in the drawings, is applicable to the exhaustion of organic matter. B B are the wooden vats lined with lead which receive the material to be displaced; G G the cullendered diaphragms for its support; and C C their movable covers counterpoised so as to admit of ready depression or elevation at will. These false bottoms are also movable, so as to afford facility in cleansing the vat, and they should, when in use, be covered with crash cloths to prevent obstruction of the holes. The tubes D D, communicating with the

steam generator, Fig. 16, traverse the centre of the vats, and are surmounted by metallic disks, E E, for the reverberation of the vapor rushing against them.

Fig. 377. Fig. 378.



The directions for the management of the apparatus are nearly the same as for displacement generally. When the vat has received its charge, the cover is to be lowered and fastened down by clamps, and steam let on by opening the stop-cock of the feeder. As the steam generates, it passes over through the pipe D, reaches the disk E, and is projected uniformly over the whole surface of the material. The elastic force of the vapor accumulating in the upper portion of the vat exerts a pressure upon that portion which has condensed, and forces it downwards through the mass. In its passage it becomes charged with soluble matter and reaches the lower part of the vat K beneath the diaphragm, whence it is drawn off through the cock L, R.

As a protection against accidents, there should be a safety-valve upon the cover of the vat as well as upon the generator.

This arrangement would be particularly economical in the arts, for extracting dyewoods and other vegetable substances.

CHAPTER XXII.

EVAPORATION.

When any liquid is heated for the purpose of expelling vaporizable matter, and the process is conducted solely with a view to saving its fixed portion, the operation is termed evaporation. It thus far differs from distillation, which has for its object the preservation of the volatilized portion, in most cases, regardless of the solid. By its aid we can decrease the volume of, or concentrate solutions for *crystallization* and chemical reaction, expel valueless volatile ingredients from those which are more fixed, obtain dissolved matter in a dry state, and prepare extracts and other pharmaceutical products.

Liquids evaporate more or less at all temperatures, those having the lowest boiling-point yielding the most readily; but there are certain conditions which greatly promote this tendency. It must be remembered, therefore :—

1. That evaporation is more rapid in dry atmospheres, and that consequently the transit of a constant stream of air over the surface of the heated liquid effects a continual removal of each stratum as it becomes saturated with vapor.

2. That evaporation is confined to the surface, and consequently that the breadth of the evaporating vessel must be extended at the expense of its depth.

3. That heat greatly facilitates evaporation by lessening the cohesive force of the particles of a liquid, and consequently that the evaporating vessel should present a broad heating surface.

4. That a diminution of the atmospheric pressure also facilitates evaporation, for the more perfect the vacuum the lower the boiling-point of a liquid.

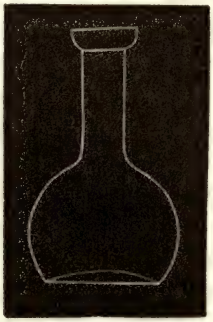
Evaporating Vessels.—For analytic purposes, capsules are by far the best implements. The capsules should be very thin, nearly flat-bottomed, with steep sides, a spout for pouring, and glazed throughout. Watch-glasses answer for small experiments, but require to be very cautiously heated, as they are readily fractured.

Beaker glasses are also used for evaporating solutions which

would lose by being transferred. Broad-mouthed glass flasks are only employed for slow processes with valuable liquids, which are liable to alteration by too much exposure when ebullition is necessary. They must be made uniformly thin throughout, of hard German glass, free from lead, and with flat-bottoms, to give them a broad heating surface and a steady position in the baths, in which they are generally placed to be heated. Figs. 379 and 380 present the usual forms of matrass for evaporations.

Fig. 379.

Fig. 380.



For the larger operations of the chemist or pharmaceutist, vessels (Fig. 381) of copper, tin, enamelled iron, tinned copper, and for some purposes very large porcelain capsules, are more suitable.

Fig. 381.

Retorts are used when the vaporized particles are of sufficient value to be condensed, as in the process of distillation.

Spontaneous Evaporation.—Those liquids which are very volatile, or which become altered by heat, are evaporated by mere exposure to the atmosphere at its ordinary temperature. To this end they are poured into broad shallow vessels, and placed aside until the dissipation of all vaporizable matters, or until crystallization; this mode of evaporation being also employed for procuring large crystals, which are better defined than those obtained by rapid evaporation.

The more dry and hot the atmosphere the more rapid is the

evaporation, because its capacity for dissolving moist vapors is much greater at high than low temperatures. In order to maintain a continued contact of the surface of the liquid with strata of fresh air, the vessel containing it should be placed in a draught, so that those portions of air which become saturated with vapor may be displaced. The air-chamber of the jack furnishes an efficient means of spontaneous evaporation.

When the air might act injuriously, and a vacuum is unnecessary, a substance may be evaporated in another atmosphere, for instance, of hydrogen or carbonic acid. For this purpose, it is only necessary to adjust the disengagement-leg of the apparatus (Fig. 172) to the tubulure of a retort, so that its end may reach nearly to the level of the liquid in the latter. The generated hydrogen passes into the retort heated to the required temperature, and promotes the discharge of the vapors into the recipient attached to the beak of the retort, and fitted with a small tube in its other tubulure for the disengagement of its uncondensed portions.

For the evaporation of solutions of sulpho-bases, of sulpho-salts, and of all substances readily oxidizable by exposure, this process is better applicable than that with the air-pump, which is apt to be attacked when the eliminated vapors are corrosive.

This process is much used in CRYSTALLIZATION, for concentrating alterable solutions, and drying precipitates.

Evaporation in Vacuo.—We have already referred to the happy influence of diminished atmospheric pressure in facilitating evaporation, and shall now speak of the means by which it is accomplished, and the particular instances in which it is employed.

This mode is resorted to for hastening the evaporation of all liquids at low temperatures, but more especially of those which would be alterable by exposure to air during the process.

In small experiments, a capped bell glass H, Fig. 47, is used as the confining space. Under this bell is placed the broad, shallow capsule, with its liquid contents, supported upon a wire tripod, resting in a leaden tray containing sulphuric acid, dried chloride of calcium, fused potassa, or some other absorbent material (DESICCATION). The bottom or bed of the bell may be a ground glass plate, and to seal the joints hermetically the rim

of the bell should be greased. Connection being made by means of a suitable pipe, and the stop-cocks between the bell and the syringe, communication is opened and the vessel exhausted of air. The pressure being thus removed, evaporation proceeds rapidly; and until the absorbent matter becomes saturated with vaporized particles, or the bell filled, there is no impediment. The latter can be partially removed by working the pump at frequent intervals.

When an air-pump is used, the procedure is the same; but, in either case, the vacuum must be produced gradually, otherwise the sudden ebullition of the liquid may cause ejection of its particles. The better way is to cease pumping as soon as the barometer attached to the machine indicates from two to two and a half inches pressure, and to resume the process of exhausting again at intervals of fifteen or thirty minutes.

Other modes of evaporating in vacuo, as practised in the arts, are fully described in Ure's Dictionary of Arts, and under *Sugar* in the "*Encyclopædia of Chemistry*," and "*Knapp's Technology*." Howard's and Barry's vacuum pans are the most effective implements. The latter, a costly instrument, is applicable in Pharmacy for making extracts upon an extensive scale. It consists of a hemispherical pan with a tightly fitting cover, in the centre of which is a bent tube leading into a copper spheroid of four times the capacity of the pan. This tube is fitted with a stop-cock, which allows a communication, at will, between the spheroid and pan. Another cock, at the opposite end, is made so as to couple with the conduit of the steam generator.

The liquid to be evaporated is introduced into the basin, which is then to be hermetically closed and placed in a water-bath. The cock connecting with the spheroid being closed, a current of steam is let on, and continued until the entire expulsion of air from the pan; access of steam is then stopped by closing the cocks, and a sheet of cold water applied to the exterior. A condensation of vapor ensues, and a partial vacuum is produced. Communication being then opened with the caldron, uniform expansion of the air ensues; and as the capacity of the spheroid is four times greater than that of the pan, the latter contains only one-fifth of its original amount of air. Several repetitions of this manipulation produce a sufficient vacuum. The water-bath is

then heated until the liquid within the pan commences to boil, as may be seen through the small window left for the purpose, and the cooling of the spheroid continued. When the liquid has reached the required thickness, the operation may be discontinued. In this way ebullition proceeds at 100° F., under a pressure sixteen times less than that of air. With an air-syringe attached, for removing the vapor as fast as formed, the power of the apparatus would be greatly increased.

Evaporation by Heat in Open Air.—Having already noted the effects of heat in facilitating evaporation, we proceed to make known its modes of application. As the boiling-points of solutions differ, so accordingly their evaporations are effected at varying temperatures. For example, aqueous or other solutions of unalterable matter may be evaporated over the fire; others, which are destructible by heat, require the intervention of BATHS. In whatever mode the operation is performed, the general principles are the same, and whether the vessel be a porcelain capsule or metallic pan, the greater its width in proportion to its depth the more rapid is the evaporation. Constant agitation with a stirrer is also promotive of the process.

Evaporation over Water and Saline Baths.—When solutions are alterable at a temperature above 212° F., the capsule or containing vessel is heated over the WATER-BATH, Fig. 150.

If it requires a higher heat, but one not exceeding 300° F., then the water must be replaced by a SALINE-BATH, p. 269.

Evaporation by Steam.—This mode has many advantages over all others, not among the least of which is that with the aid of the generator or jack, Figs. 15 and 17, any number of vessels may be heated simultaneously, and in any part of the laboratory, it being only necessary to have conduits of sufficient length to convey the steam to them, as exemplified by the steam series, Fig. 18. Moreover, convenient stop-cocks allow a regulation of the heat, and consequently all danger of injury to the evaporating solution is avoided. By increasing the pressure of the steam the temperature of the solution is also elevated.

Steam is applied through metallic coils placed at the bottom of the containing vessels, and having an exit-pipe leading into the neighboring flue, or else by means of metallic casings. This latter mode, by far the best, has already been described in detail.

Evaporation over Sand-baths.—This mode is much used in analyses and for careful evaporations, requiring temperatures greater than 212°, and yet not so high as those given by the naked fire. The position and arrangement of the vessels are as directed under the head of SAND-BATHS.

Evaporation by Heated Air.—This mode is admirably adapted for the inspissation of the natural juices of plants or for preparing dry extracts. It is also applicable to the completion of evaporations which have been carried as far as is safe over the naked fire. Porcelain plates or panes of window-glass are the vessels used, and a stove or apartment for their reception, heated from 95° to 110°, with a free draught passing through, are the means of obtaining the required temperature. The juice evaporates either to thin scales or else to a spongy mass, as in the case of tannin extracted by ether, and as soon as it reaches dryness, the plates or panes are to be withdrawn, and their contents removed with a spatula.

Marcet, of Geneva, who experimented with water and alcohol, gives the following interesting results of an investigation into the circumstances which promote or prevent the evaporation of liquids.

1. The temperature of a liquid allowed to evaporate freely in an open vessel is always inferior to that of the surrounding atmosphere. The higher the temperature of the atmosphere, the greater is the difference between its temperature and that of the liquid exposed to evaporation. Between 40° and 50° Centigrade, the difference was found to vary from 5° to 7°; between 20° and 25° it varied from 1½° to 1¼°; at 12° it was 0·8° only, and between 3° and zero about 0·2°. The explanation of this result is obvious. The evaporation of a liquid diminishing with the external temperature, the cold, which is the consequence of this evaporation, must diminish in the same proportion; and if it were possible to prevent evaporation altogether, the author presumes that there would be no difference whatever between the temperature of a liquid and that of the surrounding medium.

2. The temperature of liquids, such as water and alcohol, as well as the rapidity with which they evaporate, varies, all other circumstances remaining the same, according to the nature of the vessel in which these liquids are contained. For instance, the

temperature of the surrounding atmosphere being from 15° to 20°, water is, on the average, 0·3° warmer in an open metallic vessel than in a similar one of polished porcelain, and 0·2° warmer than in a similar one of glass. It is the same with alcohol. Again, both water and alcohol evaporate more rapidly from a porcelain vessel than from a metallic or glass vessel of precisely the same size. For example, three similar vessels, one of metal, the second of porcelain, and the third of glass, containing each 600 grains of water, having been exposed to evaporation during seven days, the temperature of the surrounding atmosphere varying from 20° to 25°, it was found that, at the end of that time, the porcelain vessel had lost 303 grains of its previous weight, the metallic one 277, and the glass vessel 275·5 grains only. The author enters into considerable detail as to the precautions he took to make sure that these differences could not be attributed to any difference in the radiating or conducting powers of the vessels employed. The differences observed in the temperature of liquids, according to the nature of the vessels in which they are contained, depends, no doubt, on the property with which these vessels appear to be endowed of accelerating or delaying evaporation. It is evident that, in each case, the quantity of sensible heat subtracted from the liquid, or, in other words, the diminution of its temperature, must be in proportion to the quantity of vapor formed. For instance, the fact that water and alcohol are constantly colder in a porcelain vessel than in a similar vessel of metal or glass, is the natural result of the more rapid evaporation of these liquids from the former of these vessels than from the two latter. The reason why a porcelain vessel evaporates more freely than a metallic or glass one is far less evident. The author has proved, by placing an hermetically closed bottle of porcelain, containing water, under the vacuum of the air-pump, that it cannot be owing to any perviousness of the sides of the vessel, as he was at first inclined to suspect.

3. The influence of the mass or depth of a liquid was next examined. The author's experiments appear to lead to the curious fact, that the rapidity with which any given liquor evaporates depends not only on the extent of its surface, but also, within certain limits, on its depth. He found, for instance, that with two similar cylindrical porcelain vessels containing, the first a

layer of water of one-twelfth of an inch in depth, and the second a layer of half an inch, the evaporation from the latter exceeded that of the former in the proportion of nearly 4 to 3. A similar result was obtained with alcohol. If thin glass vessels were used, the same increase of depth accelerated the evaporation in the proportion of 6 to 5. As the author himself observes, this apparent influence of the depth of a liquid on its evaporation may, very possibly, be merely owing to the greater facility with which the different layers are conveyed, the one after the other, to the surface, when the liquid is of a certain depth than when it is quite shallow.

4. Water containing a solution of salt in about the same proportion of sea-water, evaporates less rapidly, and, consequently, produces less cold than the same quantity of distilled water. The higher the temperature of the surrounding atmosphere, the greater the difference between the quantities of salt and fresh water evaporated in a given time, under similar circumstances.

5. A given quantity of water, mixed with certain pulverulent substances, such as a siliceous sand, for the particles of which it has but a slight adhesion, evaporates more rapidly than the same quantity of distilled water alone. The fact was ascertained in the following manner:—The author having procured two small porcelain vessels exactly of the same size, introduced into one of them 300 grains of distilled water, and into the other a small quantity of siliceous sand, over which 300 grains of water were poured, so as not only to saturate the sand, but also to leave a layer of water of about one-tenth of an inch in thickness over and above its surface. At the end of five days, it was observed that the water standing alone had lost 184 grains of its previous weight, while the water mixed with the sand had lost no less than 196 grains. The average difference, resulting from a series of experiments, was 7½ per cent. in favor of the more rapid evaporation of water mixed with sand compared with that of water standing alone. If the experiment be made with glass or metallic vessels, the difference is only about 4½ per cent.

6. The last result which we shall mention, and which may be regarded as a direct consequence of the preceding one, is the following:—Water mixed with sand remains habitually at a slightly lower temperature than an equal surface of water stand-

ing alone. The difference varies to a certain extent according to the nature of the vessels in which the experiment is performed, never, however, exceeding half a degree Centigrade. It is greater when the comparison is made between water and wet sand placed in two similar metallic vessels, than when they are placed in porcelain or glass vessels; in the latter case it seldom exceeds 0·1° to 0·2°.—*Bibliothèque Universelle*, 1853.

Evaporation over the Naked Fire.—The tendency of many substances to decomposition over fire, especially organic, even when in solution, renders this mode inapplicable save when the solvent and substance dissolved are both unalterable below the boiling-point of the former. It is resorted to for expediting evaporations, but otherwise is far more inconvenient than steam, because of its affording less facility for the regulation of the heat and requiring greater attention. The containing vessel should be placed over a furnace of small dimensions, and its contents continually stirred with a porcelain spatula;—this precaution preventing decomposition or carbonization, provided the temperature is not allowed to exceed the boiling-point of the solvent.

In analysis and other processes, the heating implement is generally the gas or spirit-lamp, Figs. 40, 41. The capsule filled to about two-thirds its depth with liquid, being placed in position, the flame is applied gradually and maintained just low enough to prevent ebullition; and in order to facilitate the process, and at the same time to allay turbulence, it should be frequently stirred with a glass rod. The same directions apply when the operation is performed in a beaker glass, as is done in some analytic experiments; and Fig. 347 shows its position over the lamp.

A cover of white paper prevents access of dust without retarding the process, but care must be taken that the contents of the vessel be not ejected against it, thus causing a loss.

In evaporating to dryness, towards the end of the process the flame must be so managed as to impart a uniform heat to all parts of the thickened solution. The interposition of a very thin plate of sheet-iron between the flame of the lamp and the bottom of the heating vessel is an additional means of preventing spirting. These precautions and constant stirring will prevent the loss of particles, which is liable to occur upon the disengagement of the last portions of liquid. If the liquid drops a powder

during the operation, the vessel must be inclined; and in order to prevent spirting, heated above the deposit.

A platinum spatula is a very useful implement for detaching any efflorescent matter which may travel up the sides of the vessel.

CHAPTER XXIII.

CRYSTALLIZATION.

WHEN a body, in the act of passing from a liquid or gaseous to a solid state, arranges itself in symmetrical forms, the process is termed crystallization, and the parts of the body so aggregated are called crystals.

By this process we can separate crystallizable from amorphous substances dissolved in the same menstrua, purify crystals from foreign and coloring matters, and in qualitative examinations, be enabled to determine the composition of bodies by a reference to the characteristics of figure.

The modes of crystallization are by FUSION, SUBLIMATION, SOLUTION, and CHEMICAL REACTION.

Crystallization by Fusion.—Sulphur, lead, bismuth, tin, antimony, silver, numerous alloys, anhydrous salts, and other fusible substances which are unalterable by heat, are crystallizable by FUSION.

To this end they are melted at the lowest possible temperature, and allowed to cool very gradually. As soon as a crust forms upon the top, which may be readily seen by the surface becoming furrowed, it must be pierced with a rod, and the still fluid portion decanted with sufficient dexterity to prevent it from cooling during the process, and at the same time from injuring the crystals coating the interior of the vessel.

The liquid matter should be placed so as to be free from all vibration. The greater the mass of the material and the more slowly it is cooled, the more voluminous and better defined will be the crystallization.

Crystallization by Sublimation.—Volatile solids, as iodine,

camphor, several metallic chlorides and mercurial compounds, arsenic, benzoic acid, iodide of lead, &c., when heated as directed in SUBLIMATION, yield vapors which, in cooling, take the form of crystals.

Crystallization from Solution.—When it is desired to obtain a substance in crystals, it must first be liquefied or made into a SOLUTION with an appropriate liquid. If, after making the solution, there be any insoluble residue, it must be separated by FILTRATION; and subsequently, if the solution is capable of decolorization by such means, it should be boiled with a small portion of clean bone or ivory black, and again filtered. As it is the almost universal law that heat increases the solvent power of bodies, the solution should generally be made and clarified at the boiling-point, so that the excess of matter taken up at the high temperature may separate on cooling in the form of crystals.

So long as a solution is dilute it yields no crystals;—these latter are only formed when the containing liquid is supersaturated, or, in other words, holds more than it can retain in fluid form; and, consequently, in diminishing the quantity of the liquid by EVAPORATION, we increase the density of that which remains, and hence, upon cooling, it deposits that excess of the dissolved substance, which it only held by virtue of its comparatively high temperature.

Some substances are so easily soluble, and to such an unlimited extent, that their solutions form crystals immediately upon cooling; others again are taken up with such difficulty, even at high heats, unless in large bulks of liquid, that although exposed to prolonged ebullition, they require to be evaporated in order to separate what has been dissolved. As the mode of evaporating has an important influence upon the form and size of crystals, we give some hints as to the proper manner of performing it.

If large and well-defined crystals are required, the solution should be subjected to spontaneous evaporation, for the more slow and uniform the concentration, the more regular and gradual will be the superposition of material required to make distinct and large crystals. A slight addition of solution of gelatin will, in some instances, it is said, give the crystals the form of plates, as in the case of boracic acid.

The solution should be removed from the fire as soon as drops, withdrawn by a glass rod and deposited upon a watch-glass or clean spatula, give small crystals upon cooling. If, however, a very dense crystallization is required, the concentration may be continued until a pellicle forms upon the top, but then the solidified masses are confused and less brilliant. These essays indicate that the liquid is evaporated to a point at which it cannot retain all of its soluble matter. The vessels are then placed aside to cool gradually and uniformly, that the excess may crystallize out of the liquid. The temperature should be regular, for slight variations may alter the form of the crystals.

Bodies equally soluble in cold and hot water, as well as those which are deliquescent, require a prolonged evaporation, as they only crystallize from very dense solutions.

When the liquid is to be converted *wholly* into solid, then the process is termed *granulation*, and is practised by concentrating it to a syrupy consistence, removing the vessel from the fire and stirring it *constantly* until the mass has cooled into granules. This mode is adapted for purifying pearl-ash and converting it into *sal tartar*, and also for graining brown sugars.

If the liquid, evaporated as above directed, becomes colored or murky during the process from partial decomposition, it may be treated with bone-black, and again filtered into a capsule, or other vessel, previously warmed by a rinsing with hot water, so as to prevent confused crystallization from sudden contact with its cold surfaces. Blue stoneware capsules are far better than porcelain capsules or glass beakers, as they are not only more durable, but by the roughness of their interior surfaces far more promotive of crystallization. Stone basins for this purpose, called crystallizers, are made of all sizes, in depth greater than in breadth, and with a lip to facilitate the separation of the residual liquid from the crystals. This residual liquid, called the *mother water*, is usually returned to the evaporating vessel to be further concentrated for the production of a new crop of crystals, particularly if the liquid has been homogeneous.

The first crop of crystals is generally purer than subsequent ones, but may still not be sufficiently free from foreign salts and other matters, and, therefore, require to be dissolved anew and recrystallized as at first. The pure crystals are drained of their

mother water by inclining the crystallizer over the evaporating vessel long enough to allow all of the fluid to run off at the spout. The crystals are then removed with a spatula and transferred to a drainer, which is generally made of porcelain or earthenware, and after the form of a saucer or funnel, Figs. 382, 383, accord-

Fig. 382.

Fig. 383.

ing to the quantity and nature of the crystals. Thence, they are subsequently removed to the drying-frame. In the first crystallization, the mass of impure crystals is drained upon a filter, and, if necessary to free them from syrupy or dirty liquid, enclosed in a cloth and pressed (Fig. 375). Sometimes, especially when the crystals are not very soluble, they may be drenched, while upon the filter or drainer, with cold water, which carries away much soluble impurity. This solution, if valuable, may be mixed with the mother waters, and the whole, after being transferred to the evaporating vessel, be concentrated and again crystallized. The crop thus obtained is very impure, and requires to be drained on a cloth and pressed, and subjected to as many treatments with bone-black, and renewed crystallizations, as are required to remove all color. It must be remembered, however, that bone-black is only used when the coloring substance is organic, and when the characteristic color of the crystals is light, for it has no blanching action upon either organic or unorganized bodies which are naturally tinted.

In recrystallizations, only as much water as is necessary to effect solution should be used, so that the mother waters may be as small in quantity as possible. The last mother waters being incapable of yielding any more crystals, may, in some processes, be reserved for other purposes; as, for instance, making new compounds. Thus, for example, the mother waters of iodide of potassium may be used to precipitate iodide of mercury from the bichloride of that metal, or of lead from the nitrate of lead, and

those of chloride of barium to obtain carbonate of baryta, upon the addition of carbonate of soda.

Sometimes, however, crystallization is resorted to for the separation of one substance mixed with others, which are variably soluble in the same liquid, and which do not crystallize together, but separate from the solvent at different stages of concentration. In such case, the mother waters may contain one or more of the other components of the original substance, and hence are not useful for forming new compounds by PRECIPITATION. After the separation of each to the fullest extent by crystallization, at different temperature, the residue of liquor, unless it be of great value, may be thrown away.

As before said, gradual evaporation at a uniform temperature, and a perfect repose of the concentrated solution, give the most perfect crystals. Some solutions, however, crystallize less readily than others, and remain even days and weeks without exhibiting any sign of such tendency. In such cases, it is advisable to agitate the mass slightly, or to stir it gently with a glass rod. This manipulation arouses, as it were, the molecules from their inertia, and frequently determines speedy crystallization. The resulting crystals are generally, however, confused and diminutive.

To obtain large crystals from a solution which is slow in depositing them, it is sometimes proper to add nuclei to the cold solution, these consisting of well-formed large crystals of the same substance. As the solution increases its density by spontaneous evaporation, the nuclei assume a large size; but in order that their enlargement may be uniform throughout, they must be turned daily, so that the accumulation of matter may take place on all their surfaces.

This mode, as practised in the arts, is somewhat modified. The deposition surfaces are increased by inserting in the solution strings as nuclei. When one solution is thus exhausted of its soluble matter, the strings with their surrounding crystals are transferred to as many fresh vats consecutively as are required to give the crystals the proper size. In this manner, blue vitriol, prussiate of potash, tartar emetic, and rock candy are crystallized.

When the twine loops are replaced by slender twigs or branches

of wood, and the crystals are deposited in fine flakes from bulky solutions, the process is termed arborization.

Examples of arborization, where, however, crystallization is accompanied by chemical or voltaic action, are furnished by the various metallic trees, which are clusters of metallic flakes or crystals precipitated upon the surface of a dissimilar metal suspended in their solution.

Payen has suggested the following method of increasing the size and regularity of the crystals, and especially those obtained from substances soluble with difficulty.

In the apparatus employed, the liquid circulating through one part dissolves the substance to be crystallized, and deposits it in crystalline forms in another and cooler part.

"The arrangement consists of a flask or tubulated receiver, surmounted by another similar vessel, the two being adjusted by the necks, and communicating, at the lateral opening, by tubes, the one with the top and the other with the bottom of a vessel placed at some distance. The inverted receivers are both filled with the substance to be dissolved, and the whole of the apparatus with the solvent. Heat, derived from a constant and uniform source, is applied to the receivers, by which a continual circulation of the liquid is maintained, and this being saturated in the most heated part of the apparatus is conveyed to the cooler part, where the deposition takes place."

Crystallization may thus be made to take place slowly and regularly. Payen obtained, by this means and the use of benzole as the solvent, crystals of sulphur one hundred times larger than those formed in the usual way.

Crystallization by Chemical Reaction. — The newly-formed compounds, resulting from chemical reaction, frequently assume the crystalline shape. Thus, for example, antimony roasted in contact with air forms crystals of antimonious acid; chlorine acting upon phosphorus produces crystals of perchloride of phosphorus. So, likewise, crystals of bicarbonate of potassa are produced when carbonic acid is passed through a concentrated solution of carbonate of potassa.

Silver displaced from its solutions by zinc forms a crystalline deposit. Sulphate of lime precipitated by alcohol from its aqueous solution also falls in crystals. Morphia, also, and other

crystalline alkaloids, may, in like manner, be precipitated by decomposing their solutions with ammonia.

CHAPTER XXIV.

DESICCATION.

THE desiccation of a substance consists in the expulsion of its "moisture." The term moisture is used only in reference to that variable amount of water, and sometimes, though rarely, of other liquids, which it may have absorbed, or otherwise retained in a state of mechanical union. The combined water, or that of crystallization, of which many bodies are in part constituted, exists in an entirely different form, and is not usually to be expelled when the drying is preliminary to analysis. When, however, it is desired to dehydrate a body entirely, this latter water of combination is also to be dissipated.

The means of desiccation are various, and differ with the nature of the substance to be dried, its quantity, and alterability by heat and exposure.

DESICCATION OF SOLIDS.—Undecomposable salts and any substances unalterable by air or heat, may be dried by FUSION. If the amount of moisture is to be determined, the crucible and its contents should be weighed before and after the operation, the loss expressing the weight of water expelled. Those bodies, however, which will not bear the heat necessary for fusion, can be desiccated by EVAPORATION to dryness in a capsule,—care being taken to renew surfaces by constant stirring.

Those saline matters which readily yield all their water by exposure may be reduced to powder or *effloresced* by subjecting them in thin layers to a draught of dry air, which, if necessary, may be moderately heated. For this purpose, as well as for that of drying crystals which do not effloresce, it is necessary, in manufacturing laboratories, to have a special apartment. This room should be smoothly plastered within, and need not be of large size. As a means of ventilation its opposite sides are pierced with small holes, which, to prevent the admission of dirt,

are covered with wire gauze. The interior is fitted with trellis shelves for the support of the wooden frames, stretched over with white muslin, and upon which the substance rests between or upon, as may be required, folds of bibulous white paper. The heat is communicated by sheet-iron flues proceeding from a stove placed outside of the enclosure, or by means of steam-pipes fed by the generator, Fig. 15. The temperatures should range from 75° to 110° F.

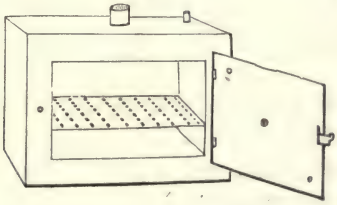
This apartment is also useful for pharmaceutical purposes, for drying plants, roots, seeds, woods, &c. They may either be suspended or spread in thin layers upon frames, and repeatedly turned for the purpose of exposing fresh surfaces.

The air-chamber, p. 40, may, to a limited extent, be made to replace this apartment, and in an experimental laboratory it is, together with the means mentioned in this chapter, sufficient for all purposes.

As the salts effloresced as above still retain a little water, they require to be repeatedly pressed between the folds of white paper until dampness ceases to be imparted to them. Sometimes a previous trituration is necessary to facilitate the process.

Filters containing precipitates, after careful removal from the funnel and compression between the folds of bibulous paper, may be further dried in the same manner. Those, however, which contain the results of analytic experiments require more careful manipulation. For their treatment a copper-plate oven is often used. It consists (Fig. 384) of a brass soldered copper box 7 ×

Fig. 384.



9 inches, enveloped by a steam-tight jacket, in the door of which are vent-holes for change of air. The water, or the olive oil which is used if the substance requires a heat higher than 212° for its desiccation, is poured through the centre aperture at the

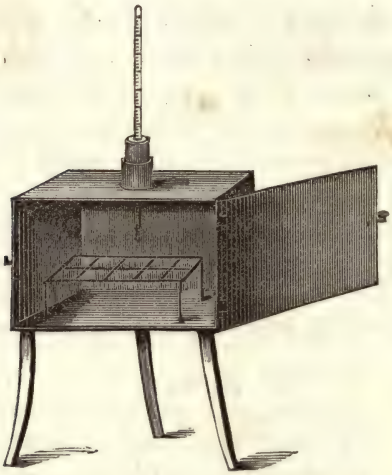
top, but must not more than half fill the jacket. The lateral opening is for the reception of a thermometer, which is adjusted by means of a perforated cork, for facilitating the regulation of the temperature.

The watch-glasses, plates, or capsules, in which the substances to be dried are placed, rest upon the perforated shelves in the interior.

The thermometer will indicate with precision the temperature of the bath, and care must be taken that the latter be not allowed to exceed the degree above which the body to be dried decomposes.

If the substance to be dried is not alterable by temperatures above 212° F. to 300°, they may be expeditiously dried in the air-box, Fig. 385, described below, which differs from the preced-

Fig. 385.



ing in receiving its heat direct from the flame, and without the intermedium of a bath. It consists of a strong brass box, 6 to 8 inches in width and depth, with a corresponding height. In the centre of the top is a circular opening, in which a thermometer is adjusted by means of a cork. A wire stand in the interior serves as a support for the containing vessels, and allows the drying of filters in funnels, when it may be inexpedient to remove them. Circular holes, in the lower and upper parts of the sides, create

a circulation of air through the box, and thus promote evaporation.

Rammelsberg's air-bath, Fig. 386, is very similar to the preceding, but allows the use of a tall chimney, which, by determining a powerful draught through the chamber, greatly expedites the drying process. It consists of a cylindrical copper box, six inches high by four inches wide, and has a loose cover, in which is adjusted a thermometer for regulating the temperature. Rising from the cover opposite to the thermometer is the chimney, which should have a height of 9 to 12 inches. One or two circular openings, at the circumference and at the base of the cylinder, are necessary for the admission of air.

Fig. 386.

A perforated diaphragm, midway in the interior, serves as a support for the crucibles, watch-glasses, capsules, funnels, and other vessels containing the matters to be dried.

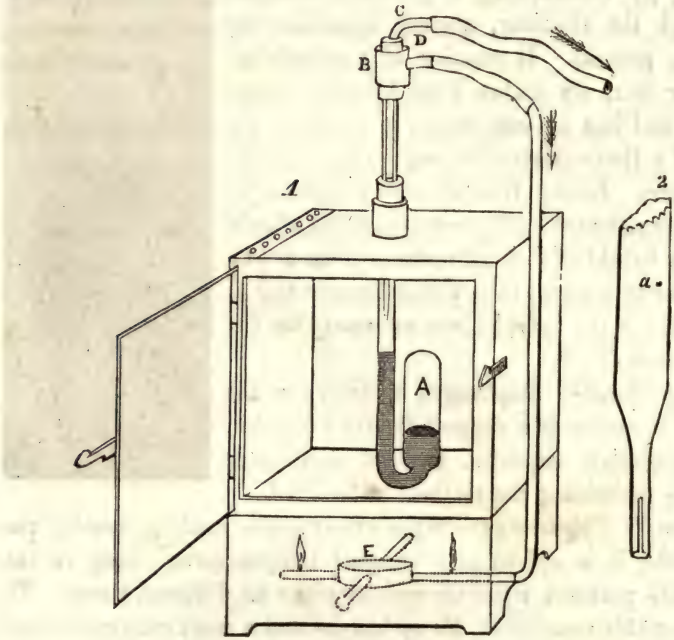
Kemp's Thermostat.—When street gas is used for heating the air-baths, it is apt to give unequal temperatures, owing to the variable pressure upon the service-pipes at different times. To prevent this annoyance, Kemp has devised a most convenient and efficient apparatus, which he properly designates a *Thermostat*, as it regulates the supply of the gas to the burner, and of course the amount of heat thus applied to the substance under process, thereby insuring a constant temperature for any length of time.

This simple and ingenious apparatus will be found serviceable for all operations requiring a prolonged temperature of great uniformity. The author used it successfully in promoting tedious fermentations, artificial incubation, and for obtaining products of the decomposition of organic bodies at fixed temperatures. The use of mercury renders it available only for temperatures below the boiling-point of that metal; but by making the instrument of iron and substituting fusible alloys for mercury, it becomes applicable for higher degrees.

The instrument itself, shown in the following drawing, consists of an air-thermometer B A of glass, and containing mercury in

the lower part of the bulb A, and a portion of the stem B. A tube of smaller diameter, as seen in the figure, passes down the axis of the tube B, the annular space being made air-tight by a

Fig. 387.



small brass stuffing-box B, which enables it to be retained at any required elevation. An air-tight connection is made at C with a piece of flexible caoutchouc tube, communicating with the service-pipe by means of a gallows-screw. The gas entering through this channel passes into the long stem of the thermometer, and thence to the burner D.

In using the instrument, the bulb A must be immersed in the water-bath with the substance under examination, if that means of heating is employed; and, in the case of an air-bath or hot press, it must be placed in immediate vicinity of the substance, so as to produce an equilibrium of temperature between the air in the bulb and the surrounding atmosphere.

The inventor thus explains its mode of operation. Supposing, for example, that it is required to keep an object at a temperature of 100° F., then the bulb of the instrument being placed

contiguous to the object, a free supply of gas is allowed to flow through the burner, and a flame ignited. The heat soon begins to act upon the air in the bulb, causing it to expand and force the mercury up the stem B; and when it is found, by the use of a common thermometer, that the heat has risen to the required degree, the inner and smaller tube is to be pushed down until its lower extremity reaches below the surface of the mercury. This would, of course, cause the flame to be extinguished; but, as the preventive of this occurrence, a small hole is bored through the inner tube above the extremity, to permit the transit of a small quantity of gas to the burner. As the passage of the gas is now interrupted, the source of heat is withdrawn, and the cooling influence of the surrounding air then causes the air contained in A to contract, and the mercury in B to sink, and leave the end of the internal tube uncovered. A free channel for the gas is thus opened, so that, as combustion proceeds, the temperature would again rise and cut off the supply; but, in a short time, these two opposing forces reach an equilibrium, and scarcely any variation in the size of the flame occurs. To insure perfect contact of the end of the inner tube with the mercury, the former, to the extent of a half inch, is made of platinum, and amalgamated by dipping it into a liquid amalgam of sodium and mercury.

Westly proposes to improve Kemp's instrument by cutting or grinding off the inner tube C on one side, so as to form a long, narrow slit in place of the small hole. This modification prevents the sudden jerks with which the aperture otherwise opens and closes.

If the extremity of the inner tube be formed into a cone, like an inverted funnel, and then a portion of the side cut off, the area of the aperture for the passage of the gas will form a parabola, or hyperbola, as required, by which the flow of gas may be regulated with great precision to the desired temperature, and in any ratio that is needed. To insure metallic contact with the mercury, the interior of the tube may be, for a short length, electrotyped with platinum.

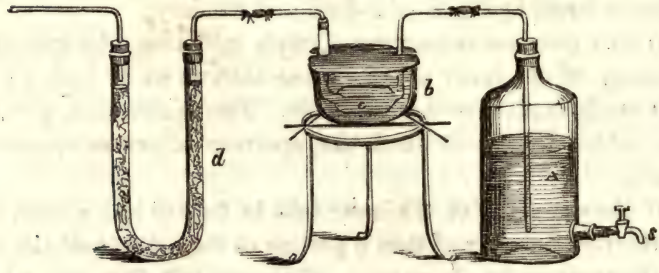
According to Wetherill, a glass tube may be made to replace that of platinum by drawing it out at the end in such a manner that the tip, to the length of three-quarters of an inch, shall have a diameter of one-sixteenth of an inch. The quarter inch of the

end immediately behind the tip is carefully filed down with an angular file, so as to produce a fine slit. By this slight modification, the extremity of the tube comes in the centre of the rising column of mercury, which closes it accurately.

The drawing presents Wetherill's adaptation of the thermostat to an air-bath; the tube being shown at 2 in full size. The hole *a*, through which the gas passes to the burner when the extremity is closed, must be only large enough to admit sufficient gas to prevent the extinction of the light. The burner employed is in the form of a cross, and consists of two pieces of brass tube closed at the end, and united by brazing in such a manner as to leave a free communication throughout the bores. The holes for the exit of the gas are drilled into the upper surface with a needle. A leaden weight E, cast at the centre of the cross, serves to give steadiness to the burner, and at the same time sufficient elevation to promote draught of air beneath. The air-bath rests upon a box of four inches height, which encloses the burner; and a movable opening gives access to the interior, as may be necessary, to light or examine the flame.

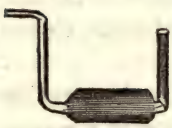
"Fig. 388 represents an arrangement for drying substances in

Fig. 388.



a current of dry air produced by the efflux of water. For this purpose a known weight of the substance is introduced into the small bent glass tube (Fig. 389), which has also been weighed; the body of this tube being then plunged into a copper water-bath *b*, charged with a saturated solution of common salt, it is kept in its place by a cover furnished with two apertures for the arms of the drying-

Fig. 389.

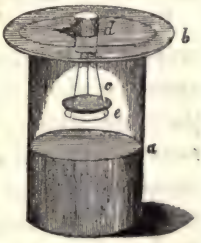


tube; the wider arm is united by means of bent tubes and a caoutchouc connector with the U-shaped tube, and containing fragments of chloride of calcium, and the narrow end is connected with a bent tube, which passes through the cork of the bottle A nearly down to its bottom. This cork must fit the bottle perfectly air-tight, and all the joints and connections of the whole apparatus must be perfect. The bottle A is filled with water, which, on turning the stop-cock *s*, flows out in a small stream, its place being supplied by the air drawn through *c*, and which becomes dried during its passage through the chloride of calcium, tube *b*. The bath is charged with water, a saturated solution of common salt, or of chloride of calcium, according to the degree of heat required, and it is kept boiling by means of a spirit or gas lamp placed underneath."

Desiccation of easily Alterable Substances.—It has already been said that the power of absorbing and retaining moisture varies in different bodies. This property renders the use of those which have it in the greatest degree available for the drying of others which are deficient in it. The substances subjected to this mode of drying are mostly organic bodies, and those readily alterable by heat or exposure, but which yield their moisture much below 212° F.

A very simple method of accomplishing this kind of desiccation is to suspend the substance in a beaker glass *b*, over a large volume of sulphuric acid *a*, Fig. 390. The rim of the glass is ground for the purpose of making a tight joint with the ground-glass plate cover *d*, which has a hole in the centre for the support of a cork, with the tray and wires *e* suspended to it. Upon this tray rests the watch-glass or capsule *c*, which contains the substance under process. The rim should be greased previous to placing the cover upon it, so as to render the connection air-tight.

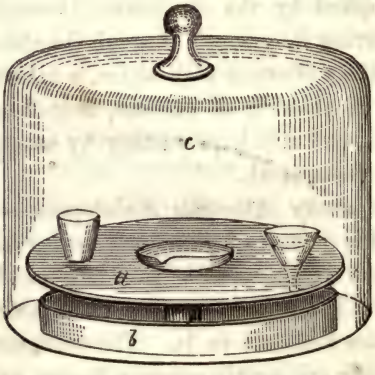
Fig. 390.



The sulphuric acid absorbs the moisture as fast as it arises from the substances, and thus maintains constant dryness of the internal atmosphere. When the substance has ceased to lose weight, the operation is finished.

Another arrangement for the same purpose consists of a large bell glass, fitting accurately upon a ground-glass plate or bed. Within is a shallow saucer *b*, containing dry chloride of calcium, strong sulphuric acid, or other highly absorbent material, and over it a perforated glass support *a*, upon which rest the capsules, crucibles, beaker, watch-glass, or other containing vessels. Fig. 391 exhibits the whole arrangement. The rim of the bell, as also

Fig. 391.

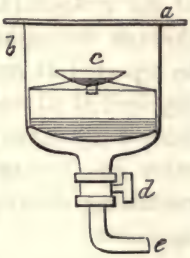


that part of the plate which it touches, are to be greased, in order to make the joint hermetical. The material thus exposed to dry air continues to lose moisture until all has been expelled, or until the absorbent matter has become saturated; in such case the latter must be replaced with a fresh quantity.

By substituting the bed of an air-pump for the glass disk as a support for the other parts of the apparatus, otherwise arranged exactly as above described and shown in the figure, and increasing the evaporation by exhausting the air, desiccation proceeds much more rapidly and effectually. A partial vacuum being thus produced the drying substance liberates its aqueous vapor freely, new portions being given off as soon as those which preceded them are condensed by the absorbent in the saucer, which is usually, in these cases, fused chloride of calcium or strong sulphuric acid, those agents absorbing watery vapors perhaps to a greater extent than any other. The process is thus continued until complete desiccation of the substance and saturation of the absorbent material ensue, the latter being renewed as often as may be necessary.

If the eliminated vapors are corrosive, it is advisable to modify the arrangement, so that they may be neutralized as fast as generated, otherwise the metallic surfaces of the air-pump will be injured. A suitable apparatus is shown in Fig. 392. It is an inverted bell glass, fitted at its neck with a stop-cock, by which it connects with a tube containing pumice-stone impregnated with acid or alkali, according to the nature of the vapors to be absorbed. The substance to be dried and the absorbent or hygroscopic body are arranged within the bell in the usual manner. The latter is then greased at its edges, hermetically covered with a ground-glass plate, and exhausted of air by a syringe coupled with the further end of the drying or chlorcalcium tube *e*.

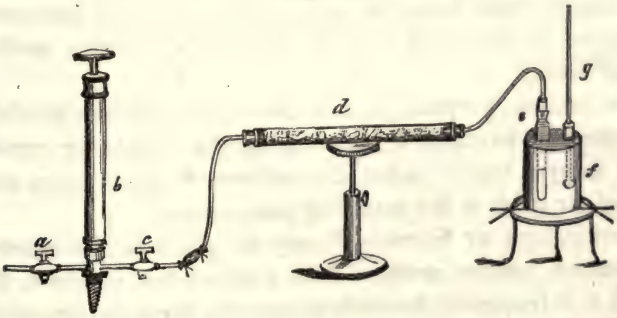
Fig. 392.



By having a bed of ground-glass instead of metal, and detached from the pump or syringe, and made to communicate with it by flexible lead pipe and gallows-screws only when exhaustion is required, an apparatus is made, which, as represented in Fig. 391, becomes available for all the purposes of evaporation and desiccation.

Another mode of drying alterable and fixed substances in vacuo is shown by the arrangement, Fig. 393, which effects a repeated change of air. It consists of a copper cylinder box, soldered

Fig. 393.



with brass, having two apertures in its top,—one, *g*, for the reception of a thermometer by which to regulate the temperature, and the other for a glass tube *e*, the recipient of the substance to

be dried. This tube is connected by means of a smaller glass tube *i*, tightly adjusted in perforated corks with the chloride of calcium tube *d*, and thence also with the exhausting syringe *b*. Heat being applied to the bath by means of a small furnace or gas lamp, a partial vacuum is then produced by several strokes of the syringe piston. In a few moments air is to be admitted through the cocks *c* and *a*, and this exhaustion and airing is to be repeated at occasional intervals, the air in its transit being deprived of all moisture by the chloride of calcium. When it is desired to replace atmospheric air by carbonic acid, hydrogen, or other gas, it may be introduced by connecting the gasometer, containing the required gas, by suitable couplings with the same apparatus.

Desiccation of Liquids.—Desiccation properly means the freeing of a body, capable of existing in a dry state, from accidental moisture. But, for the sake of uniformity of description, we have applied the term also to the separation, from fluids, of water, which is the ordinary source of moisture. This is usually done by the agitation with the liquid of some absorbent material, which either unites with the water, forming a stratum of different density capable of being separated by filtration or decantation; or else combines with it so firmly that the fluid, which is usually more volatile, can be separated by distillation.

Thus alcohol and other spirits are rectified by distillation over carbonate of potassa, chloride of calcium, or free lime, it being only necessary to stop the process as soon as the liquid comes over slowly, which indicates that all the pure spirit has passed. Agitation of ether with any of the same absorbents produces similar results.

For analytic purposes, and in minute experiments, accidental moisture may be expelled from liquids less volatile, by exposing them in open vessels under the receiver of an air-pump, as described for solids in the preceding paragraphs.

Desiccation of Gases.—Nearly all gases in the course of elimination become involved with more or less moisture, from which it is frequently desirable to separate them previous to their application to chemical reaction. For this purpose they are passed over some highly absorbent material, such as dried chloride of calcium, quicklime, or sulphuric acid.

The simplest arrangement for the purpose is given at Fig. 218, which exhibits a straight tube *d d*, containing the dried chloride of calcium, adapted at one end by means of a perforated cork with the gas generator A, and at the other, in like manner, with a disengagement-tube *e e*. The gas in its transit through the chlorcalcium tube is relieved of its moisture. This tube varies in size from half to one inch diameter, and eight to twelve inches length, according to the quantity of gas to be desiccated. The chloride of calcium can be replaced by quicklime, potassa, or pumice-stone impregnated with sulphuric acid, as the nature of the gas may require; but in either case the solid material should be in small lumps. The water formed during the process collects in this tube.

Liebig uses the drying-tube of such a form as is shown at Fig. 394. It differs from the above in having a bulb, and in being

Fig. 394.

drawn out at one end to a fine tube, thus leaving but one aperture to be corked. Lumps of absorbent matter are placed in the bulb, and coarse powder of the same substance in the long part, each end of which is very loosely plugged with raw cotton to prevent the exit of particles.

For small operations, the bent form, Fig. 395, is most convenient, as it is easily adjusted to the mouth of the bottle without the necessity of multiplying joints. The bulbs, in these two latter tubes, serve also as wells for the reception of the condensed vapor.

Fig. 395.

Dumas's vertical drying-tube, designed for the desiccation of large quantities of very moist gas, is so constructed that the condensed vapor instead of remaining in contact with the pumice, and thus impairing its absorbent power, will be deposited in the lower part. The tube leading from the generating vessel is adapted by means of a perforated cork to a lateral tubulure at the base. The disengagement-tube is similarly adapted to the top.

The selection of the drying, or hygroscopic material, must, as

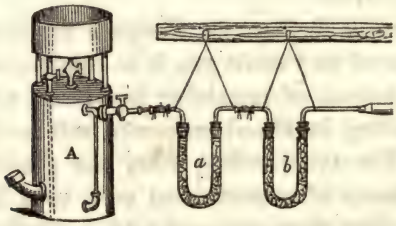
before said, be made with a regard to the nature of the gas; thus, for example, quicklime should never, for obvious reasons, be used for desiccating chlorine, or other gases which combine with it chemically; for the drying of nearly all such gases an acid body may be employed, and pumice-stone, in lumps of about the size of half of a pea, impregnated with sulphuric acid, is very serviceable, as it presents a large extent of surface. For this purpose, however, the pumice must be freed from all the chlorides which it contains, otherwise the sulphuric acid will disengage muriatic acid, possibly to the great detriment of the gas which is undergoing drying. The best way is to pulverize and moisten it with sulphuric acid, and subject it to calcination in a crucible. When, after constant stirring, it ceases to disengage acid vapors, the operation is finished.

Anhydrous phosphoric acid is also occasionally employed as a drier, but only in very nice experiments. It is mixed with clean asbestos, which occupies the same position in the tube as any of the other absorbents.

As a means of perfect desiccation it is often required to combine the absorbent powers of two different materials in one apparatus, and for this purpose the U-form of drying-tube is most convenient. It presents a large extent of surface in a limited space. There is, however, a disadvantage in arranging and adjusting its parts firmly together, and also in the necessity of occasionally renewing the hygroscopic substance more frequently than in the straight tubes.

Fig. 396 exhibits a proper arrangement of the U-tubes for the

Fig. 396.



desiccation of gas. By this mode the gas may be introduced directly from the generating vessel, as shown at Fig. 218, or from

a gas bag or gasometer as seen in the preceding drawing. The latter communicates with a pair of U-shaped glass tubes, which are connected together by means of bent tubes, perforated corks, and flexible india-rubber joints. In one of their legs is placed dried chloride of calcium, and in the opposite one asbestos, or lumps of pumice-stone, impregnated with sulphuric acid. The reservoir on the top of the gasometer being filled with water, and its pressure applied by opening the cocks, a stream of gas is gradually expelled, and in its transit through the tubes is freed from its moisture by the absorbents.

CHAPTER XXV.

PRECIPITATION.

THIS process is employed for the immediate separation of a body in the solid state, both from mechanico-chemical and simple solutions. The reagent, which is used to produce the action, is termed the *precipitant*, and the resulting deposit the *precipitate*.

Bodies, in some instances, may be precipitated unaltered, but in most cases, being the result of chemical reaction, are modified or entirely changed in their nature. Thus, for example, sulphate of lime may be precipitated from its simple aqueous solution by alcohol;—this latter, by union with the water, forming a liquid in which that salt is insoluble. For like reasons, the resins are precipitated from alcoholic solutions by water; and gutta-percha from solution in chloroform by ether. If, however, carbonate of soda or other soluble carbonate is substituted for the alcohol, in the instance of sulphate of lime, then the original combination is broken up by the action of double elective affinity, an exchange of bases taking place, and insoluble carbonate of lime precipitating instead of the unaltered sulphate, as in the instance with alcohol. So, also, an analogous result would ensue by virtue of simple elective affinity if soda is used instead of the carbonate, the lime then partially falling in a free state, having been deprived of its sulphuric acid by the caustic alkali.

The consistence of the precipitate and its form and color vary with the nature of the solutions, and the rapidity with which it

is produced. These distinctive features serve as characteristics by which, in analysis, the presence of certain bodies is determined.

The precipitate is differently termed according to its appearance. It is *flocculent* when it falls in small flakes or flocculæ, like those produced by ammonia in solutions of peroxide of iron; *pulverulent*, when in fine powder and compact, like the sulphates of lead or of baryta; *granular*, if deposited in minute irregular molecules; *crystalline*, when it subsides in minute crystals, as the bitartrate of potassa, sulphates of silver and of lime; *curdy*, when *cheesy*, like that thrown down by chloride of sodium from nitrate of silver, and *gelatinous*, when of the consistence of jelly, as alumina freshly separated from alum by carbonate of potassa.

Precipitating Vessels.—The most convenient vessels, used in analysis, are beaker glasses, or wide-mouth flasks, the latter being used only when the process is to be practised upon the boiling liquid. When solutions are precipitated, especially for the purpose of collecting the precipitates, the form of the vessel may be that of the one in the drawing, Fig. 397, which insures the subsidence of all the deposit, and prevents particles from adhering to the sides. They may be of glass or blue stoneware, according to the amount of liquid under process.

Fig. 397.

In chemical investigations, test-tubes are the most convenient implements. They permit the operator to use minute quantities, and they are readily heated and shaken. As a precipitate is, in some instances, not perceptible for some hours, especially in dilute solutions, sufficient time should be allowed to elapse before deciding upon the reaction of a precipitant upon a solution.

Directions for Precipitating.—Both the material and reagent must be in solution and separately clarified by filtration before being commingled, otherwise the suspended matters will subside with the precipitate. As heat generally promotes the reaction and the subsidence of the precipitate, the solution should, in such cases, be warmed, or even made hot, and the reagent cautiously added during continual stirring with a glass rod, so that all parts of the liquid may be brought in contact. The vessel is then set

aside upon a sand-bath, or in a warm place, until the deposition of the precipitate has left the supernatant liquor clear. A few more drops of precipitant are then added, and, if all the matter has been thrown down, they will produce neither precipitate nor cloudiness; but if a portion still remains in solution, still more of the reagent must be added. The addition of the reagent or precipitant must be gradual, for besides the waste of material and inconvenience of washing it out, an excess, in certain instances, redissolves the precipitate. As soon as a drop or two of reagent ceases to give cloudiness or precipitate in its descent through the supernatant liquid of the settled solution, its addition must be discontinued and the vessel placed aside, and, after sufficient repose, subjected to DECANTATION or FILTRATION to separate the solid from the liquid portion, the latter of which is also usually to be reserved in analysis or when it is of value, as it may contain other newly-formed compounds dissolved in the menstruum employed.

When the precipitate about to be formed is somewhat soluble in the liquid of the original solution, the amount of that liquid must be diminished by evaporation, and the precipitation effected in a concentrated solution; for example, in the reaction of solutions of strontia with sulphuric acid or soluble sulphates.

Metals may be precipitated from their solution by other metals having a greater affinity for oxygen than is possessed by those in combination; thus copper may be precipitated from its sulphate by iron, lead from the nitrate by zinc, and silver, arsenic, and mercury, from their solutions by copper. A slight acidulation of the liquid facilitates the process, and the metallic strips used as reagents must be clean and bright.

Metals are also precipitated by voltaic action, a familiar instance of which is the art of plating by GALVANISM.

CHAPTER XXVI.

DECANTATION—FILTRATION.

Precipitates, which are substances deposited by any means from liquids in which they have been dissolved or chemically

combined, may be separated either by decantation or filtration. The first mode is applicable to those solids which are of much greater density than the menstrua containing them, and which readily and rapidly subside, forming heavy compact deposits. In delicate experiments, however, and in all cases where the liquid is turbid and deposits its suspended matter reluctantly, the latter plan is the most appropriate.

Besides being a process subsequent to PRECIPITATION, for the separation of the clear supernatant liquor from the subsident matter, decantation is also useful in LEVIGATION. For WASHING precipitates, which require a large amount of water, or frequent renewals of the wash waters, it is much more convenient than filtration. This latter mode, however, must, as before said, be always adhered to in analyses, and when the precipitate is light and apt to be disturbed during decantation.

Decantation from small vessels in nice experiments is practised by gently inclining the vessel, whether it be a capsule, as at Fig. 398, or a beaker glass, Fig. 399, and allowing the liquid to run

Fig. 398.

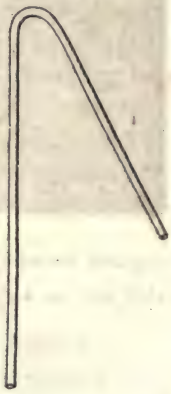
Fig. 399.

down in a continuous stream along a glass rod placed against its rim or edge. This operation of *pouring* requires a degree of dexterity which is indispensable in analytic operations in order to avoid loss of material. The exact position of the rod is shown in the figures. When the pouring is completed, the rod should be tilted upwards for a moment, so as to prevent the loss of adherent drops, and immediately returned to the vessel, the edge of which should be slightly greased so as to effectually prevent any particle of liquid from passing over. These precautions are only necessary in the decantation and filtration of liquids, during analytic processes; so much care being unnecessary in less im-

portant manipulations, as it is of little consequence if the liquid does carry over a little of the precipitate or suffers a slight loss. If the bulk of liquid is very small, it may be removed with pipettes, Figs. 106, 109, p. 199; for larger quantities a syphon is requisite. This implement may be of glass or lead tubes, the former being cleanly and of more general application than the latter. The shapes given in the drawings refer to those of either material.

Syphons.—The most simple form of syphon, Fig. 400, is similar to an inverted V, with its opposite branches of unequal length. The long leg may be from 12 to 20 inches in length, the shorter one proportionably less. The clear diameter is from an eighth to a half inch, according to the extent of the operation.

Fig. 400.



This syphon is inserted and filled with water or any other liquid which is without action upon that in the vessel; the mouth of the longer leg is then closed with the finger, and the shorter branch introduced, mouth downwards, into the liquid to be decanted, until it nearly reaches to the level of the precipitate without disturbing it. Upon removing the finger, the liquid runs out in a continuous stream, and may be almost wholly drawn off by slightly inclining the vessel.

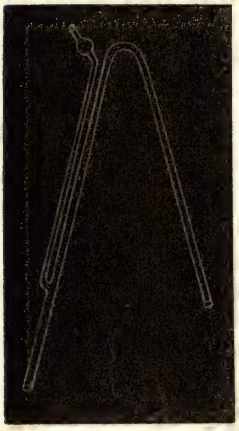
The rationale of the operation is as follows:—When the short leg of the syphon is dipped into water the liquid mounts into the tube as high as the surface of that which is in the containing vessel. Now, the weight of the atmosphere bears equally upon the surface of that in the vessel and in the syphon, but if the elastic force of the internal air is removed or diminished by suction with the mouth at the other end, or by having previously filled the syphon with water, the liquid runs over, and as the weight of the column of water in the long leg is greater than that in the short one, the flow will be continuous while the mouth of the short leg is immersed in liquid, for no air can enter to produce an interruption.

If the liquid is not injurious or unpleasant to the taste, the

syphon may be inserted in the liquid without previous filling,—suction with the mouth at the long end drawing it over.

For the decantation of caustic liquids the syphon is furnished with a lateral tube, as shown in Fig. 401, which serves as a protection to the mouth. Its application is similar to that of the one described above (p. 495); the short leg is dipped into the liquid to be decanted, the lower end closed with the finger, and suction practised at the orifice of the supplementary tube until the air is removed and the liquid runs over and almost reaches the mouth, when the decantation goes on continuously after the withdrawal of the mouth and finger.

Fig. 401.



The annexed drawing, Fig. 402, exhibits these syphons in operation.

A length of cotton wick doubled in syphon form, and having its short end immersed in the liquid, also acts as a syphon, but is much slower in its operation.

Fig. 402.

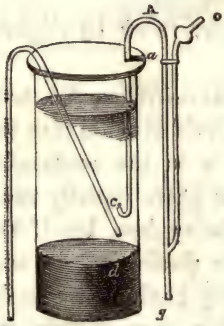
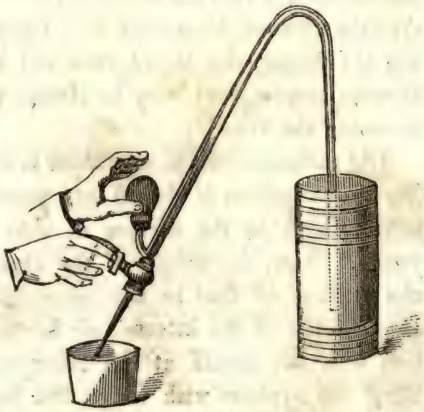


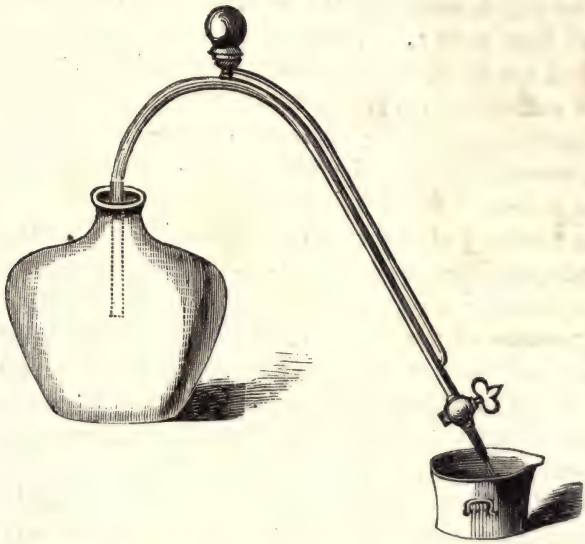
Fig. 403.



Coffee's syphon, Figs. 403, 404, which may be made of either glass or metal, after the forms presented by the drawings, are much more convenient than either of the preceding patterns, as they deliver the clear liquid without the least inconvenience to the operator.

It is made to work by closing the cock, compressing the india-rubber ball, which forms a cap to the lateral tube, and quickly immersing the short leg in the liquid to be drawn off. The hand being removed from the ball causes the latter to resume its shape, and, consequently, a partial vacuum in the tube, which is imme-

Fig. 404.



diately supplied by the liquid running up to fill it, under the outward pressure of the air, as far as the bend, and therefore when the cock is opened, it drops by the force of gravitation, and flows off in a continuous stream, as long as the mouth of the short leg is covered by it.

The use of the syphon allows the separation of the liquid without disturbance of the settled matter, but as the latter still retains more or less fluid which cannot be separated in this way, it may be thrown upon a filter, and, in large operations, even subjected to pressure in cloths, as directed at p. 460.

FILTRATION.—The mode most commonly resorted to, for separating solid substances from liquids in which they are suspended, is that of *filtration*, and it is also occasionally but rarely used for the purpose of disuniting liquids. The process consists in passing the mixture through suitable media of sufficient porosity to allow the transit of the liquid portions while they intercept

any solid particles. For the separation of liquids the texture of the medium must be such that it is penetrable by or attractive of the one, but impervious to the other, of them, as it is upon this that the success of the operation depends; thus, for example, moistened paper will allow the passage of water, but not of oil.

Paper, brown muslin, linen, crash, woollen and canton flannel, felt, raw cotton, sand, asbestos, crushed quartz, bone-black, each and all have their appropriate application as media, and when thus used are all styled *filters* or strainers; the first title being almost exclusively applied to those of paper supported upon funnels, while the latter is limited to the other textures or bodies which are either suspended upon frames for pharmaceutical operations or deposited in proper vessels.

This process is of equal importance in chemical and pharmaceutical operations. In analysis it enables us to separate precipitates or insoluble residue from liquids, and to obtain each free from particles of the other,—an indispensable condition where both are to be further acted upon for obtaining accurate results; while, in ordinary operations, we can by its aid free liquids from dirt and other foreign matters, and render them transparent.

FILTRATION THROUGH PAPER.—Paper is more generally used, particularly in delicate experiments, than any other medium. It is advisable always to use that which is *white*,[1] for it contains no coloring matter to deteriorate the liquid which traverses it. Moreover, it should be free from saline impurities which are soluble in acid or alkaline liquids, otherwise the accuracy of analytic results may be materially interfered with.

The laboratory should be provided with two qualities of paper, one of fine quality for nice investigations, and another somewhat inferior for the less important processes. There are certain conditions requisite in both kinds. They should be unsized, yet strong, and while sufficiently porous to allow the ready passage of the liquid, compact enough in texture to retain all the solid portions.

"*German filtering paper*" answers very well for all general purposes; but for analytic investigations that known as "Swe-

[1] A porous kind of thick brown paper is made from a mixture of woollen and other rags for filtering tinctures and the coarser liquids of an aqueous or spirituous nature.

dish" *filtering* paper is best. Being made expressly for the purpose and of purified rags, it is free from lime, copper, and salts, which have to be removed from other paper by treatment with pure hydrochloric acid and repeated rinsings in distilled water before it becomes fit for such uses.

The Swedish paper is whiter and thinner than the German, and is made with great care; and leaves by incineration only $\frac{1}{250}$th of its weight of ashes, an important point in analyses where the amount and nature of the ashes left by the paper require to be considered.

The paper drawer should be kept always supplied with a stock of filters of all the required sizes. The use of the Swedish paper should be limited to the filtration of finely divided precipitates. The greater porosity of the German renders it more applicable for rapid filtration, and as it is much less expensive, all large filters should be formed of it.

The filters must be circular, and cut by tin patterns, which should consist of different sizes of $2\frac{1}{4}$, 3, $3\frac{3}{4}$, $4\frac{1}{2}$, 6, $7\frac{1}{2}$, 9, and 12 inches in diameter. This mode of cutting different sized filters from one sheet of paper is economical, and saves the waste which would be occasioned by indiscriminate use of the paper, while many serious delays may be prevented by having a supply always at hand.

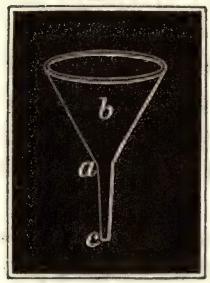
The ashes of the piece of Swedish filter of each size must be determined by incinerating one and accurately weighing the residue, and engraving its weight upon the tin pattern by which it is formed. Thus, in analyses, we can know by reference to the figures the amount of fixed matter (ash) in each particular size.

The supports for these circular filters, folded into conical form as hereafter directed, are *funnels*, which vary in material and form according to the nature of the operation. They may be of glass, porcelain, or stoneware. The first, free from lead, are of almost general application for analytic purposes, and the latter two for pharmaceutical. Funnels of metal are seldom required in the laboratory, a very few instances only demanding the use of lead or platinum.

The glass funnels should be made with straight sides, inclining to an angle of about 60°. This shape, Fig. 405, is indispensable for the smaller funnels used in analyses, as it forms in its inte-

rior a true cone, which allows the admission of a larger amount of liquid in a small space. The pint funnels, and those of still larger size, may have an inclination of ten degrees less, but if their section has not nearly the form of an equilateral triangle, the filters fit badly and work imperfectly. The funnel should be slightly round at the shoulder *a*, where the apex of the conical filter rests; and, moreover, the end of the barrel *c* ought to be cut at an angle of 30°, so as to present an oblique termination, as these points promote filtration.

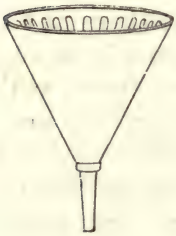
Fig. 405.



The laboratory must be supplied with a series of funnels, ranging as follows, $1\frac{1}{4}$, $1\frac{3}{4}$, 2, $2\frac{1}{2}$, $3\frac{1}{4}$, $4\frac{1}{4}$, $5\frac{1}{4}$, and $6\frac{1}{2}$ inches in the greatest diameter of the body *b*. Of the smaller sizes, it will be well to have duplicates or triplicates as they are the most frequently employed. The stock is not complete without one or two miniature funnels of thin glass for filtering into test-tubes in qualitative investigations; and one or two of convenient size with long barrels *c*, for charging retorts and deep vessels.

Sometimes the glass funnels are ground at the rim, so as to be tightly closed by a glass disk, but being expensive, they are only used in rare instances.

Fig. 406.



Funnels are sometimes made of porcelain with longitudinal ribs in the interior of the body, as shown at Fig. 406, for preventing the adhesion of the filter to the sides in the filtration of large quantities of bulky precipitates. The object is, however, not effected by these means, for the paper sinks into the channels and adheres to the surface, and still retards the passage of the liquid. A better way will be to use the plaited filters, Fig. 416.

Funnels are also made of porcelain, and more seldom of stoneware. They are less fragile, and more applicable to the filtration of very acid and corrosive liquids, and some other few purposes, than those of glass; but those of porcelain are not less costly. The form of those usually found in the market are shown in the

annexed drawing. They are all glazed throughout and made very strong, and those used for transferring liquids from one vessel to another have the convenience of handles. In this respect they are preferable to the glass vessels, which by frequent rough handling are more apt to be broken. Fig. 407 exhibits the form used for acids, and Fig. 408 the same funnel ribbed in its interior. Figs. 409 and 410 present the less conve-

Fig. 407.

Fig. 408.

Fig. 409.

Fig. 410.

Fig 411.

Fig. 412.

nient globular shape. Those shown at Figs. 411 and 412, cullendered at the base, are the most convenient of all, being very useful for draining crystals, for the filtration of viscous solutions through cloth filters, and for small operations of lixiviation.

Separating Funnels.—In addition to the above there are two other kinds of funnels used for separating liquids which have no

Fig. 413.

Fig. 414.

chemical affinity, and differ in density. They are fitted with stop-cocks in their barrels, as shown in Figs. 413 and 414; and

one is stoppered also at the top to prevent evaporation when volatile liquids are under process.

The mixed liquids of oil and water, or ether and water, for instance, are poured in the mouth, and after sufficient repose for the deposition of the heavier of the two, it can be drawn off by opening the stop-cock, which may be immediately closed as soon as all has passed. The lighter liquid which is thus retained may afterwards be transferred in the same way to another bottle.

Filters Folded and introduced into Funnels.—Two kinds of filters are generally employed, the plain, Fig. 415, and the plaited, Fig. 416. The former are used in analyses and whenever the

Fig. 415.

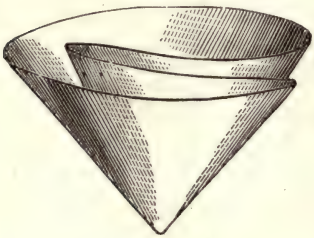
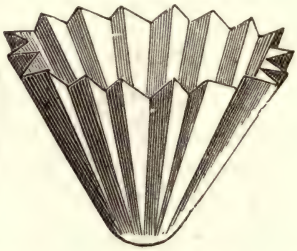


Fig. 416.



suspended or precipitated matters of a liquid are to be preserved. It is almost impossible to entirely remove the solid matter from the folds of a plaited filter, consequently such are chiefly applicable for the filtration of bulky precipitates from large quantities of liquid. This mode of folding a filter prevents its close adhesion to the glass, and greatly expedites the process by increasing the surface, and by allowing a bubble of air to ascend in the fold every time that a drop of liquid descends from the filter.

The plain filters are folded as follows:—

"When a filtration is to be performed, one of these circular

Fig. 417.

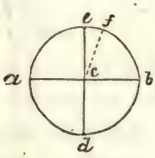
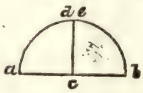


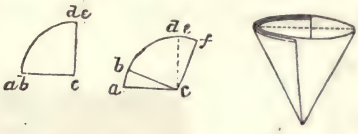
Fig. 418.



papers of the proper size is selected (Fig. 417), and then doubled

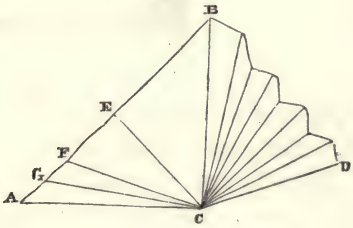
over one of its diameters (*a b*, Figs. 417 and 418), and then over the radius (*c e*, Figs. 418 and 419) perpendicular to the first diameter, so as to form a quadrant. One of the folds is then opened,

Fig. 419. Fig. 420. Fig. 421.



forming a hollow cone, as represented in Fig. 421, which will fit accurately in the funnel, if the sides of the latter form an angle of 60°. If the angle be greater or smaller, it is necessary to double the filter the second time over another radius (*c f*, Figs. 417 and 420), not perpendicular to the first diameter, and then open the large or small fold (*a c f*, or *b c f*, Fig. 420) according to the angle of the funnel, and this repeated until a coincidence of the filter with the inside of the funnel is effected."

Fig. 422.



To form the plaited filter, take a square of paper and fold it diagonally, as in Fig. 422; turn A upon B to obtain the crease E, and open it; then double A upon E in the same direction, to make the plait F, and double the plait A back upon F, so as to form the crease G, and holding this plait between the fingers make the fold between F and D. Divide the spaces between E B and B D in the same manner.

The filters, as above made, after having their folds opened, as at Figs. 415 and 416, are placed in the funnels, and so adjusted as to fit nicely to the sides. In order to secure an uninterrupted flow of the liquid, and to prevent the breaking of the filter, the apex must not extend too far into the barrel of the funnel. Moreover, the filter should be a little smaller than the funnel, for

if it reaches to the rim, evaporation of the liquid ensues from the edges, and thus, in analyses, may be a source of error.

The proper position of the plain filter in the funnel is shown at Fig. 424, and that of a plaited one at Fig. 423.

In using large funnels the filter may be supported by a plug of raw cotton placed in the barrel at its junction with the body.

Fig. 423.

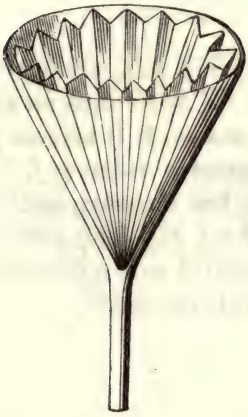
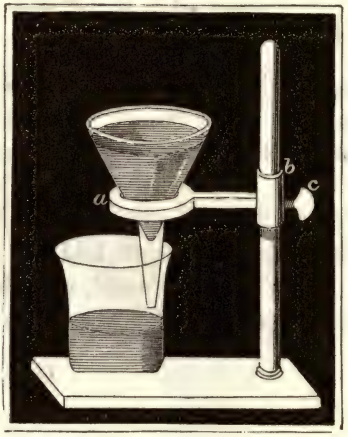


Fig. 424.



The usual support for funnels is the convenient portable stand, Fig. 424. It consists of a wooden upright *b*, screwed into a wooden bed-plate. The arm *a*, which it carries, has a circular aperture sloping inwardly and downwards, which supports the funnel steadily in its place. The screw *c* allows the elevation or depression of this arm at will, as the height of the receiving-vessel beneath may require.

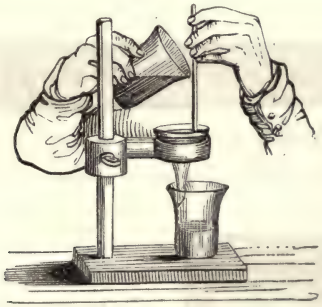
When the funnel is used for transferring or filtering liquids into narrow-mouthed vessels, its barrel may be supported by their neck; but in order to secure a free passage of air, it should be fluted externally, or else have a chip or two placed between it and the inner sides of the neck, otherwise the confined air will retard the process, and possibly force the filtered liquid, with a hissing sound, up and over the sides and mouth of the bottle.

After having adjusted the filter to the funnel, the latter is placed in the stand, so that its barrel may rest against the inner wall of the receiving-vessel beneath. This position allows the falling fluid to trickle quietly down the sides, and prevents the

splashing which would occur if it fell directly upon the surface of the liquid, and also obviates the necessity of sinking the barrel far into the receiver.

The filtering apparatus having been thus arranged, the filter is to be moistened with distilled water from the bottle (Fig. 355) or when the nature of the process requires, with a portion of the solvent liquid, and the excess allowed to trickle through, rather than be emptied out by inverting the funnel. This previous soaking of the filter greatly facilitates the operation, for dry paper absorbs water directly, and in the case of a turbid solution, while becoming more impervious to the suspended particles than it would be if the liquid which contains them were allowed to penetrate at once into the filter, it gives also a more ready passage to the clear fluid. The edges of the containing vessel are now to be slightly greased in one spot, so that in pouring there may be no adhesion of drops or trickling over the sides. It is then grasped by the right hand and brought over the funnel, while the left hand holds the glass rod at a right angle against the edge of the glass, as shown at Fig. 425. The end of this rod

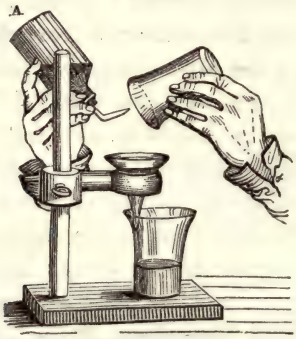
Fig. 425.



should merely reach the filter without touching it, for fear of abrasion; and the liquid should be allowed to flow down its length in a gentle stream at first against the sides, and as the precipitate accumulates it may be allowed to fall in the centre, as there is then less risk of splashing. The filter should never be entirely filled, and as it often requires many pourings to pass the whole of the liquid, great care must be taken in returning the rod to the vessel that nothing be lost. The last particles may be rinsed from the vessel and rod by the jet of the spritz bottle A (Fig.

426), by inclining both to the positions shown in the drawing below. If any remaining particles still obstinately adhere to the

Fig. 426.



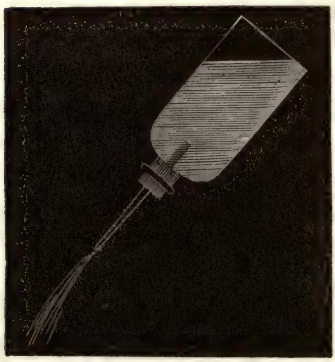
sides of the glass, or of the rod, they must be loosened by the feather end of a goosequill, and then washed out as before by the jet of the spritz. When all the liquid has passed through, the precipitate must be washed down from the sides of the filter by the force of the jet of water from the spritz.

The spritz, or washing-bottle, consists of a twelve ounce vial,

Fig 427.

to the mouth of which is adapted, by means of a perforated cork, a glass tube, drawn out at its upper end as shown in Fig. 427, which represents at the same time its exact dimensions. The bottle is rather more than half filled with water, and by blowing into it through the tube the air is compressed, and when the bottle is quickly inverted it forces out the water through the orifice in a strong jet, which may be directed to any desired point. The bottle, complete, is exhibited at Fig. 428. For washing out beaker glasses, or other deep vessels, a curved jet

Fig. 428.



is more convenient, and is seen at A, Fig. 426. An india-rubber ball may replace the bottle, it being only necessary to fit the tube in the neck, and tighten the joint with a twine wrapping. This instrument is managed as directed for the pipette, p. 200.

When hot water is required, the bottle should be of copper, tinned on the inside, of at least a pint capacity, and of the form presented by Fig. 429. It is heated as directed at p. 231, Fig. 185, and to prevent burning of the hand, is fitted with a non-conducting handle. Upon inversion of the bottle, the water is driven through the tube *d* in a strong jet by the elastic force of the confined vapor.

Fig. 429.

In dusty apartments, both funnel and receiving-vessels should be kept covered by circular or square pieces of window-glass. The one over the receiver should have an opening in the side for the passage of the barrel or tube of the funnel.

The receivers are most generally beaker glasses, but capsules, flasks, and narrow-necked bottles are all made use of. The above precautions refer especially to filtrations in analytic operations. In larger operations the manipulation is not, necessarily, so strict, and when the dimensions of the containing vessel will not admit of convenient handling, its contents may be conveyed to the filter by ladlesful in the small porcelain dipper, Fig. 430. The ladle, during the intervals of the transfers, must rest in a plate, and not be placed anywhere in the dust.

Fig. 430.

In order to expedite the process, the liquid, as a general rule, should be allowed sufficient repose previous to filtration, to deposit if possible all its suspended matter, and the clear supernatant portion should be passed through first. The subsident matter being added last, is filtered, as it were, alone, and offers no impediment by obstructing the pores of the filter to the passage of the liquid portion, as it would if mixed with it. As an exception to this rule, certain precipitates which are curdy, gelatinous, flocculent, or crystalline, may be filtered immediately after their formation. As warmth usually expedites the process, nearly all liquids, when circumstances permit, should be filtered whilst hot.

Below is a drawing of an apparatus, Fig. 431, convenient for keeping liquids warm during the operation, and known as Hare's filter-bath. It consists of an oval copper jacket, flat at top and bottom, with two conical apertures through its body. The cone, with its expanded part directed downwards, is a sort of chimney, under which a spirit-lamp is placed to heat the water in the bath, and the other is a bed for the funnel. To prevent ignition of the vapors when inflammable liquids are under process, there is a partition beneath.

Fig. 431.

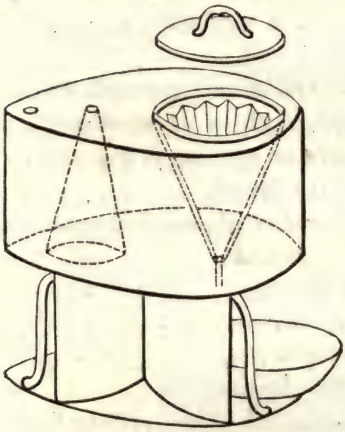
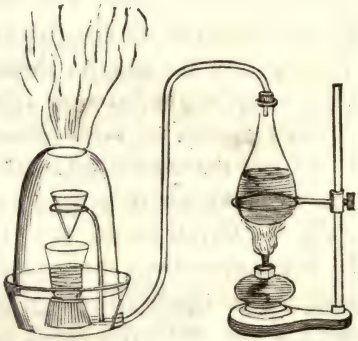


Fig. 432.



This apparatus is particularly applicable for the filtration of oils and viscous liquids. For small operations, such as analytical experiments, it may be conveniently replaced by a very simple arrangement, suggested by Normandy. It consists of a common glass flask two-thirds full of water, and connected by a leaden pipe with a circular dish, having a rim in the interior for the support of a bell glass with an open mouth. The beaker which receives the filtrate is placed upon a stand in the centre of the dish, and above it is the paper filter supported in a platinum ring, as seen in the drawing, Fig. 432.

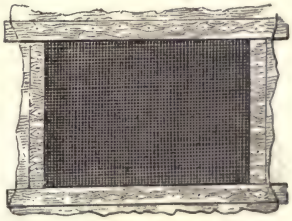
Heat being applied to the flask, steam is soon generated, and, passing into the bell, eventually escapes through the mouth. The filter being thus constantly surrounded by an atmosphere of hot vapor, not only delivers its filtrate clear and rapidly, but also free from the action of atmospheric air.

For filtrations of heavy precipitates, or a large amount of liquid, it is advisable to use the filter doubled, or even trebled, as it will be thus enabled to resist a very heavy weight. This precaution is necessary also when the liquid runs through a single paper turbid. When only the first runnings are turbid, a single filter will answer for small experiments, but the liquid must be repassed through the same medium.

FILTRATION THROUGH CLOTHS.—In large operations, or when the solid matter to be separated is too heavy, or would corrode or clog the pores of paper, the latter is replaced by cloth. The kinds of cloth vary, and each of those already mentioned has its appropriate application. The texture of the medium must be adapted to the consistence of the liquid; for example, flannel or felt may be used for filtering mucilaginous, saccharine, and slightly acidulous solutions; twilled cotton or canton flannel for oils; linen and muslin for tinctures, vegetable juices, and dilute alkaline lyes. Sieves of bolting cloth are occasionally used for filtering liquids from very fine or flocculent matters.

Filters made of the materials above-mentioned, and which take the name of strainers, instead of being used like those of paper, are suspended upon square frames formed of four pieces of lath, as shown at Fig. 433. These frames, of which there should be several sizes, must be strongly jointed, and should have inserted upon their upper surfaces a number of rectantangular hooks, similar to those used in the drying-lofts of calico factories for hanging up the printed goods. The cloth, of whatever kind, being cut into a square of size proportioned to that of the frame, is stretched over it very loosely, and retained in position by hitching its margin on these tacks or hooks. This mode is far preferable to that of nailing the cloth down with flat-headed tacks, for besides the injury of material, there is less convenience in removing it after the filtration for pressure, or for replacing it with another when it is required. The support for these strainers is an upright

Fig 433.



stand, Fig. 434, the interval between the legs of which is sufficient to allow the free entrance of the receiving-vessel.

Fig. 434.

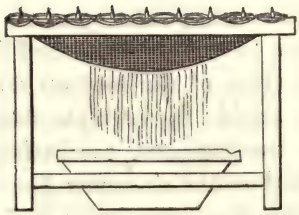
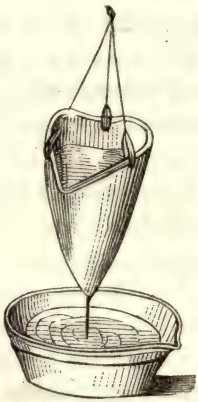
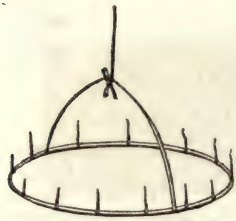


Fig. 435.



When the cloths are made into conical bags, as is very often the case, and not without advantage, they are to be suspended by loops to a transverse beam, as shown in Fig. 435. The loops or hangers are fastened to the ring, Fig. 436, around which the rim of the bag is hooked. These bags allow the convenience of using narrow-mouthed receivers, as the liquid trickles through in a stream from the most depending parts.

Fig. 436.



The texture of the straining-cloth must be porous, but sufficiently compact to prevent the passage of any solid particles. It is far more convenient than paper for coarse filtration of decoctions, tinctures, oils, syrups, and for separating liquids from solid organic matters. In most instances, the cloth or bag may be renovated by washing, and thus be rendered fit for other operations.

Before stretching the cloth upon the frame, or suspending the bags, they should be first moistened with water, or, if necessary, with a portion of the solvent liquor, in order to swell the fibres and contract the meshes. The liquid should be then introduced gradually without spilling. For this purpose, a tinned, copper, or porcelain ladle, Fig. 437, with a wooden handle, is very con-

venient. A very excellent substitute is a dipper, made from a cocoa-nut shell, and sold in any of the furnishing shops. Addi-

Fig. 437.

tions of liquid should be made until the filter is nearly full, and it should be kept at the same level by renewing it as fast as it runs through. If the first runnings are turbid, they should be returned to the filter, and if they continue murky, repassed through a fresh cloth.

After all the liquid has passed through in this way, the cloth or bag is to be unhooked, carried to a table, securely folded, and enveloped in a wrapper, and subjected to pressure as directed at p. 459, for the expulsion of the retained portion of liquid. The precipitate thus pressed, when an object of value, is to be cut up with a spatula and spread on frames for DESICCATION.

The cloths are then to be immediately rinsed and cleaned in water without soap, dried, and placed away for service at another time.

FILTRATION THROUGH PULVERULENT MATTER. — Crushed quartz, clean white sand, asbestos, bone-black, and charcoal, are the materials generally used as media. The two latter act both as filtering and purifying agents, as the liquid becomes not only clarified in its passage, but freed from coloring and putrescent matters, if any exist in it. The others are used for the filtration of very acid or corrosive liquids, which would be destructive of paper or cloth, and partially solvent of bone-black.

All of these substances may be used in funnels, a thin stratum being placed in the bottom of the body, and prevented from escaping through the barrel by a loose cotton plug in the neck.

A funnel plugged in this manner, even without the stratum of pulverulent medium, answers an excellent purpose for the filtration of liquids which pass through freely, and whose suspended matter is in coarse particles.

It will of course be remembered that the use of these media is only practicable when the liquid is the sole object of value, for it would be impossible to prevent at least the partial admixture of the suspended matter with the secerning agent.

The asbestos, sand, and charcoal, should first be treated with

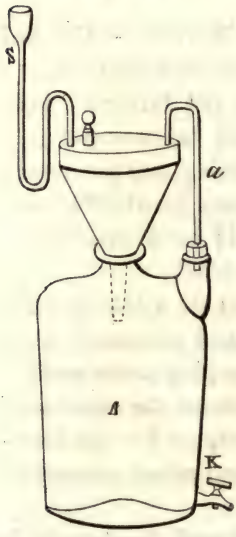
muriatic acid to remove soluble matters, and then thoroughly rinsed with fresh water to remove all traces of acid previous to their employment as filtering means. Freshly prepared and finely powdered charcoal, by its absorbent power, deprives most liquors of their fetor and organic coloring matter; bone-black has the same effect, but in a much less degree. These two are the best substances for separating impurities from syrups and aqueous liquids.

The filtering substance should always, before being used, be moistened throughout, as in displacement, with clean fluid, or, as is proper in many cases, with the pure liquid which is the solvent of the various substances in the fluid which is to be depurated. Thus the substance in the funnel may be made to imbibe water before the filtration through it of a syrup, and alcohol or ether before the passage of tinctures or ethereal solutions.

Filtration by DISPLACEMENT, to which the above mode is in some respects similar, has already been fully described at p. 452.

FILTRATION OF VOLATILE LIQUIDS.—Donovan has contrived an apparatus for filtering liquids which are vaporizable or alterable by exposure to air. It is identical in principle and construction with the displacer, Fig. 372, and is very useful for filtering alcoholic, ethereal, or ammoniacal, and alterable caustic liquids.

Fig. 438.



The modification of Riouffe is more convenient than the original apparatus, as it allows the use of an ordinary funnel with a cover. It is represented by Fig. 438, and consists of a glass bottle A, with two necks, into one of which enters the barrel of the funnel. The neck of this funnel is loosely closed with a plug of raw cotton, and the liquid is introduced through the S tube without uncovering or disturbing the apparatus, As the liquid filters through, the column of air displaced finds a vent through the narrow tube *a*, adjusted in position by means of perforated corks. The stop-cock K allows the withdrawal of the filtrate at pleasure.

CHAPTER XXVII.

WASHING.

In all precipitations, the powder thrown down becomes involved with more or less of the original liquid from which it has been deposited. As these liquid portions are impurities, they must be separated; and in many large operations, and when the precipitate is bulky, we effect their removal by repeated washing and DECANTATION; but when the powder is light, and in all cases where accuracy in estimating results is required, the purification is conducted by pouring continued streams of water or other fluid through the substance contained on the filter.

Washing by decantation is usually practised by diffusing the precipitate in a large quantity of cold or hot water, or other suitable liquid, as circumstances may require or admit; stirring well, and after sufficient repose for settling, decanting the clear supernatant solution. A repetition of additions of fresh water, and subsequent decantations after repose, will entirely remove all soluble matter and free the precipitate from impurity.

Fig. 439.

In analyses, the precipitate is most generally washed upon the filter by projecting water from the spritz bottle A, Fig. 426, the jet of which, by its force, at the same time loosens that portion adhering to the sides, and concentrates it all at the bottom, when a larger amount of washing liquid may be added from the bottle, Fig. 55. To give force to the issuing jet, as is sometimes necessary in detaching particles from the filter, the tubes of the spritz may be as shown in Figs. 439, 440. The compression of the air in the interior by blowing in the tube *a* produces a jet through the lateral one *b*, drawn out to a small orifice. This form of spritz is much more convenient for large filters than the smaller one, Fig. 428; either, however, allows the direction of the stream to any desired part of the filter. The above-mentioned

bottle is flat-bottomed, and of thin glass, so as to answer for the use of boiling liquid.

Fig. 440.

The copper flask, Fig. 240, with tubes fitted to its mouth as above described, is, however, far more convenient, and less liable to receive injury.

Fig. 441.

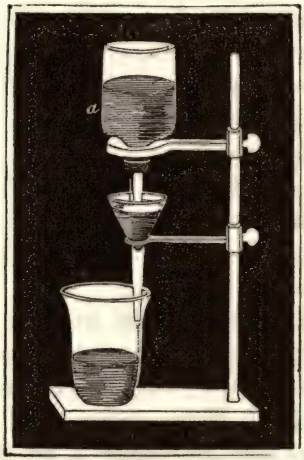


Fig. 442.

The precipitate being in this manner kept constantly mingled with liquid, is soon freed from its soluble matter. The latter fact is known when a drop of the wash-liquor, which has passed through, leaves no stain upon a silver or platinum spatula heated over the spirit-lamp.

There are many precipitates which require protracted washing, or *edulcoration*, as it is sometimes termed, in order to cleanse them thoroughly, and the bottle for the purpose is so constructed as to be self-operating in a measure, this mode being a great saving of time and labor to the operator. Fig. 441 represents the whole arrangement, which is so contrived that by a suitably constructed tube *b*, adapted, by means of a perforated cork, to the flask or bottle *a*, the water therein contained flows out very gradually, and in quantity proportional to its passage through the filter. The tube is that known as Berzelius's. It may be well replaced by two separate tubes, which can be readily formed over the blowpipe flame by the operator himself; and the modified implement is shown at Fig. 442.

Below are the two forms of washing tubes, both acting upon the same principle. Fig. 443 represents the one devised by Berzelius, and Fig. 444 that by Gmelin.

The mode of washing by these bottles is very convenient. They are nearly filled with water, and inverted over the funnel in such a position that the part *c* extends below the surface of the liquid and no further. The flow continues in a constant current without further attention until the surface of water in the filter rises towards the line *e f*, Fig. 444, and diminishes the pressing column, when capillarity is in excess and no more water flows. But as the water slowly percolates through the filter, the column is increased, and the water again flows. This alternate action is continued until the bottle is emptied.

The great convenience of this arrangement is that a filter may be washed during the absence or inattention of the operator.

If the precipitate is soluble in water, it must be washed with alcohol, ether, or other liquid, which is without action upon it.

When the bottle filled with water is inverted, as in Fig. 441, there will be no efflux of water from the small opening *c*, Fig. 444, so long as this point is at a certain distance below the curve of the syphon; but if the moistened finger, or other body, be held to the point *c*, water will flow freely from it, and air-bubbles will ascend through *i b* to supply its place. If the tubes and opening were of large size, the water would flow out with touching the end of the tube; but being of small diameter, and the end c being drawn out finely, the efflux of water is opposed by

capillary attraction. The column of water between *e f* and *g h* is the force tending to overcome the capillary resistance. If this column be lengthened by drawing *c d* further through the cork,

Fig. 443.

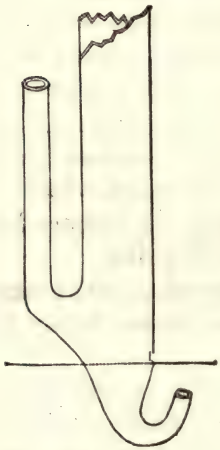
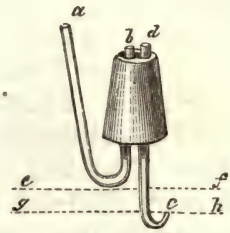


Fig. 444.



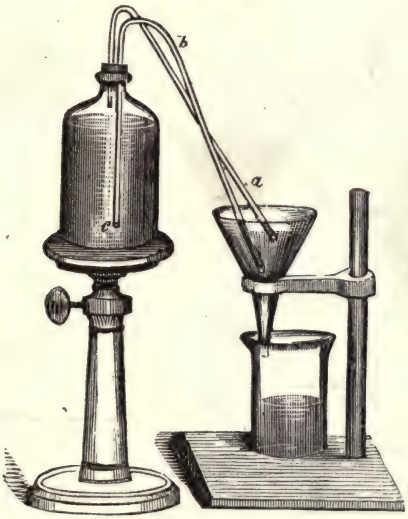
then the water will flow out of *e* spontaneously. If *c d* be pushed in just so far that the water does not flow spontaneously, then the capillary resistance slightly predominates. Then if a substance to which water adheres by adhesive attraction, be applied to the end of *c*, it will make the water flow so long as it is held there, because the adhesive attraction of the touching overcomes the capillary action. If *c d* be thrust still further into the cork, then capillary action predominates so greatly that no adhesive force can counteract it, and the water will consequently not flow out. There is, therefore, a particular medium position for the point *c*, where it will act as desired.

For other than analytic operations, the washing arrangement may be as shown by Fig. 445.

It consists of a wide-mouth bottle, with two perforations in the cork, through which pass the bent tubes *a* and *b*. One of those bent tubes descends nearly to the bottom of the bottle, as at *c*; the other stops below the cork. The outer legs of the tubes dip into the filter, the one, *b*, deeply, and the other, *a*, just under the surface of the contained liquid. The apparatus being ready, air is to be drawn through the tube *b* by mouth suction at the end until

the liquid rises and flows over into the filter. The current thus established will continue until the level of the liquid in the funnel

Fig. 445.



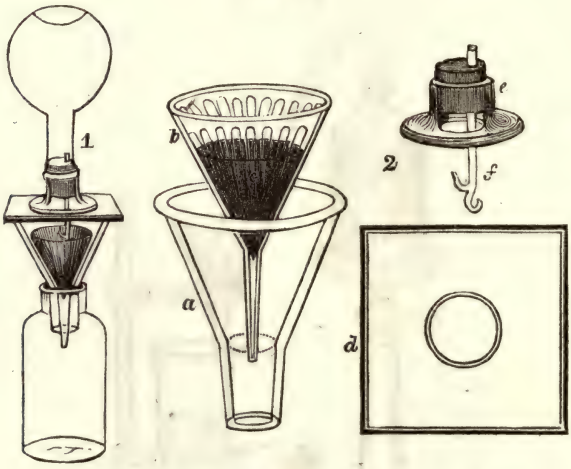
is uniform with the end *c* of the tube *b* in the bottle, and then cease. As the latter, however, falls in proportion as the filtration proceeds, it will, of course, from time to time, open the mouth of the tube *a*, and the air entering at such intervals supplies the pressure necessary to preserve the continuity of the stream of liquid.

As it is very frequently requisite to wash precipitates with volatile liquids, J. P. Cooke has suggested an arrangement for the purpose, which combines efficiency with simplicity and cheapness. It is also applicable for continuous filtration, or for filtration either in vacuo or in an atmosphere of any gas that is desirable. Moreover, it protects the filter from the dust and fumes of the laboratory, even when the exclusion of air is not essential.

The complete arrangement is shown at Fig. 446 (1), and "consists of a wide-mouth glass bottle, into the neck of which is firmly ground with emery a funnel *a*, having a short but large spout. These are made sufficiently thick to resist the atmospheric pressure, and the rim of the funnel is ground so that the apparatus may be closed air-tight by means of a glass plate. Within the

outer funnel the common filtering funnel is placed, resting loosely against its side, so as to allow free passage of air." This funnel

Fig. 446.



and some other parts of the apparatus are shown in enlarged views at 2.

"In order to wash a precipitate, or to produce a vacuum in the interior of the apparatus, a glass plate, with a hole an inch or more in diameter, drilled through its centre *d*, is substituted for the covering plate. Through this passes the tube of a washing-bottle *f*; and this washing-bottle is of the usual construction, except that it is fitted with a cork which projects about an inch above the neck. This upper end of the cork fits the neck of a glass plate, ground on the under side, as is represented at *e*. The plate is about three inches in diameter, and when resting on the plate *d*, covers the opening completely, and permits sufficient lateral motion to bring the stream of water on different parts of the precipitate. A vacuum is readily obtained by connecting the apparatus with an air-pump by means of a flexible tube having a brass plate at the end sufficiently large to cover the opening in the plate *d*, and by an easy manipulation, the interior may afterwards be filled with hydrogen or any other gas."

CHAPTER XXVIII.

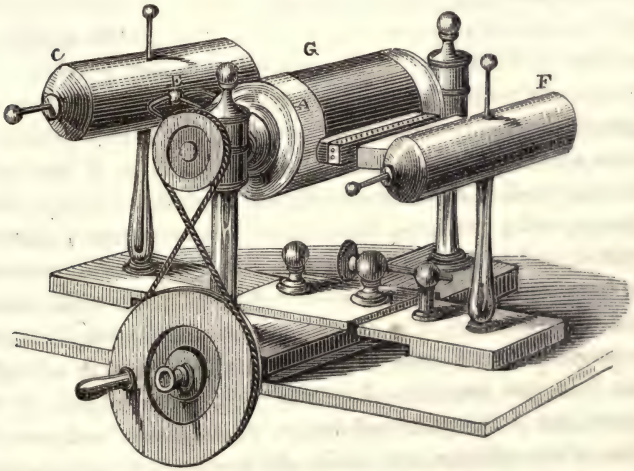
THE PRACTICAL RELATIONS OF ELECTRICITY.

THIS chapter will refer to the most ready and efficient means of developing, detecting, and applying electrical action; and will comprise information upon the practical points of electricity excited by friction as in the use of the electrical machines; of electricity evolved by chemical means as in the working of the galvanic battery; and also of electricity induced by magnetic force, as in the operation of electro-magnetic apparatus.

We will open the subject with instruction as to the manner of developing electricity by mechanical action, and describe the most approved forms of electrical machines. The works of Faraday, De La Rive, Hare, Noad, and Smead, will afford full information upon theoretical points.

The Cylinder Electrical Machine is shown in Fig. 447. A is a glass cylinder, the axis of which works in two wooden supports

Fig. 447.



fixed vertically in a solid frame. The cylinder is made to revolve by turning a winch connected by a crossed band to a wheel attached to one end of the axis of the cylinder. F, the negative conductor, is a brass tube supported by a glass pillar, and has

upon the side nearest the glass cylinder the *rubber*, or leather cushion, which presses against the glass. To the cushion is attached the flap of silk G, which extends over the cylinder nearly to the points of the positive conductor C. A screw, passing through two nuts, is so placed below as to regulate the pressure of the rubber upon the glass, by increasing or lessening, as may be necessary, the distance between the movable pedestal upon which the former stands and the main supports of the machine. At the opposite side of the cylinder is the positive or prime conductor C, being like the other conductor a tube of metal, and also insulated and furnished with balls for the transference of the electricity; but having, instead of a rubber, a collector E, made hollow, and of sheet brass, and provided with sharp-pointed projections, which almost touch the surface of the cylinder.

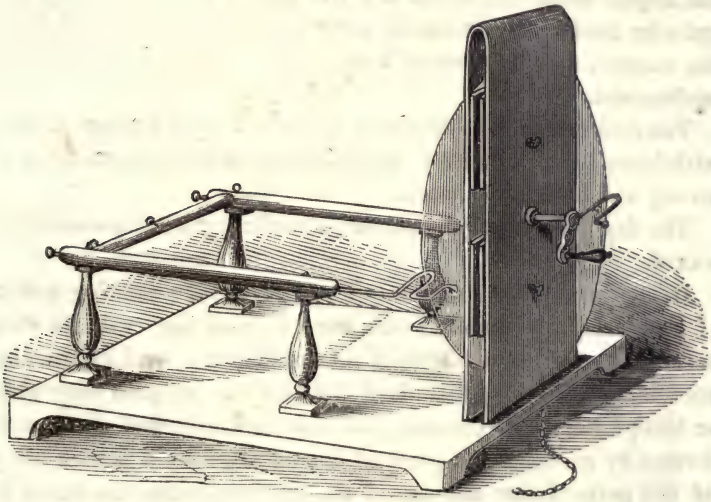
This machine is made to develope electricity by turning the winch, which causes the small wheel and attached cylinder to revolve with accelerated rapidity. By the friction of the rubber,—covered with a metallic amalgam,—upon the glass, the electricity acquired by the glass is decomposed, its positive element remaining attached to the glass, and its negative one to the cushion. The former, prevented from escaping by the non-conducting flap of silk, is carried round with the glass, and,—after a series of alterations, by induction, of the equilibrium of that portion of the fluid naturally present in the conductor,—finally by passing into it through the highly conducting collector, fills it with positive or vitreous electricity, which can be drawn off from it into other conducting bodies, either insensibly or in sparks. The negative conductor, while insulated, becomes in the same way negatively electrified, and is capable of giving sparks to, or rather receiving them from, other bodies oppositely influenced; but while unconnected with the earth, it gives off but a small amount of its positive component, and soon returns to its former state of equilibrium from its negative electricity being neutralized by the positive kind of the prime conductor, which passes back over the surface of the cylinder, and which also reaches it by other sources of imperfect conduction.

If much positive excitement is desired, the conductor to which the rubber is attached, must be kept in connection with the earth by a metallic chain or wire. When, on the contrary, the object

is to obtain negative electricity from its proper collector, the prime conductor must be made to communicate with the earth by similar means.

The Plate Electrical Machine.—This is a modification of the cylinder machine, and is preferable on account of its simplicity and greater power. In damp weather, too, it is much more reliable and efficient. The figure shows this machine in its details.

Fig. 448.



It consists of a circular glass plate, from one-twelfth to one-eighth of an inch in thickness, and varying in diameter from one to five feet. The plate is traversed at its centre by a metallic axis, fixed solidly to the glass by two clamp-nuts. The axis rests upon two upright wooden supports fixed in a frame, and is so arranged as to hold the glass in a central position. A pair of cushions is fixed to the supports above and below the axis, and so placed as to exert a considerable pressure upon the plate. A rotary motion is given to the plate by a glass handle attached to one end of the axis. Two insulated conductors, joined by a metallic rod, are placed parallel to the axis, and near the circumference of the plate. One end of each conductor encompasses the glass plate, and is fitted with points to draw off the electricity. A chain fastened to the wooden supports serves to connect the machine with the earth. As thus arranged, the plate machine only fur-

nishes positive electricity; if negative electricity is required, the conductors must be made to communicate with the earth by a chain; and if negative and positive electricity are needed, it becomes necessary to insulate the cushions.

Great care is requisite in the construction and arrangement of all the parts of the electrical machine. The quality of the glass is the most important point. It should be well annealed, strong, smooth, and even. The best glass is that which contains the largest amount of silica, and has potash for a base. In the cylinder machine all moisture must be carefully expelled from the interior, and its openings hermetically sealed with cement or sealing-wax.

The cushions are pads made of soft (buckskin) leather stuffed with horse-hair, and should be sufficiently elastic to maintain a strong and uniform pressure.

The flap attached to the rubber, of ordinary silk, is sometimes waxed.

It has been found that, in order to render the exciting power of the rubber greater, it is necessary to coat the cushions with *an amalgam.* The amalgam of tin and mercury, used for making mirrors, mixed with a little lard, answers the purpose very well, or bisulphuret of tin (mosaic gold) may be used; but the best is formed by adding to six parts of heated mercury a melted alloy of two parts of zinc and one of tin, and triturating the whole in a mortar until cold. This amalgam is made into an unctuous mass with tallow, and the cushions thoroughly covered with it. The cylinder is made to revolve, and the excess of the amalgam is removed with a cloth. The presence of little specks of the amalgam on the cylinder appears to be rather beneficial than otherwise.

The conductors, in order to preserve the electricity, must be cylindrical and rounded at the ends, and otherwise free from all angular points or projections other than the points which conduct off the current from the glass. They may be made of sheet brass, or of wood smoothly covered with tin foil. The supports must be good insulators, and covered with a varnish of shell-lac; and they should also be fixed firmly into the frame of the machine and the conductors themselves.

Electrical machines are most effective in dry and cold weather.

Any dampness in the atmosphere is unfavorable to the development of electricity. To put a machine in good order, it should be carefully freed from dust and moisture; this latter is best insured by exposure of the machine before a fire, or wiping the glass portions with a cloth moistened with ether. Care also should be taken to have the communication of certain parts with the earth as perfect as possible; and to accomplish this, the chain of the opposite conductor, from which it is desired to obtain the electricity, may be connected with the water or gas pipes of a house, or any good conducting substance which penetrates the moist earth.

When the machine works properly, after a few turns of the cylinder, it gives off a vivid spark with a crackling noise upon the approach of the knuckle or a metallic ball to the insulated conductor.

The Leyden Jar.—This apparatus, as shown by Fig. 449, is employed for the accumulation of electricity by *induction*, and is the agent chiefly made use of for laboratory purposes. It consists of a wide-mouthed thin glass jar, varying in size, neatly coated on its inner and outer surfaces to within about one quarter of its height from the top, with tin foil. The stopper is made of cork or dry wood, and is firmly inserted and well varnished. Through its centre passes a metallic rod terminating on the exterior in a smooth round ball, and the interior in a point, or bunch of diverging wires, communicating with the inner coating. The ball at the top of the rod should be at least a half inch in diameter. The stoppers and uncovered portion of the glass should be thickly covered with shell-lac varnish. A common vial, containing iron filings, and covered on the outside with foil up to the level of the metal within, and provided with a rod and ball, as above described, makes a very good Leyden jar.

Fig. 449.

In order to charge the jar the electrical machine must be put in motion, and the jar held in the hand, so that the knob touches that conductor of the machine which contains the kind of electricity it is desired to collect in the jar. The inner coating of a Leyden jar is easily charged with negative electricity by holding

it by the knob and putting its outer coating in contact with the prime conductor of the machine. When charged, it is necessary to place it upon an insulated table; for if touched by a conducting medium, it would cause an unpleasant shock to the operator.

The electricity often accumulates in the inner coating until its tension becomes so great that the equilibrium of both coatings is restored by a discharge from one surface to the other taking place. For this reason it is not safe to use very large jars, as any imperfection in the glass, which would render a particular part weaker than the rest, would make it liable to fracture by the mutual attraction of the two electricities, which would effect a union by breaking the glass.

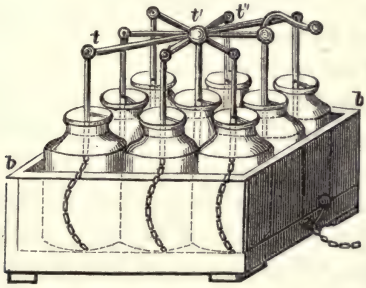
When one kind of electricity is collected in the interior, the opposite sort is produced in the exterior coating, or,—in accordance with the theory which admits the existence of only one kind, —when it is in excess in the inside, it is deficient in the same ratio upon the outside. The tendency is then always to restore that neutrality, or natural order of things in which the influence is not made evident to the senses; but in a good Leyden jar, the parts should be so arranged as to permit the collection of a large amount of electricity before a spontaneous discharge takes place. If the jar, before becoming highly charged, permits such an escape, it is usually an evidence that there is a hole or crack in the glass, that the uncovered surface has become a partly conducting one from the presence upon it of moisture or dust, or finally, that the outer metallic coating extends up so far as to allow of the easy passage of a spark to it from the rod or ball. The last condition can be altered by lessening the height of the outer covering of foil, taking care to reduce that which is within also to the same level. To expel moisture and dust, the vessel should be warmed and wiped, as before directed for other parts of the apparatus.

The retention for some time, of the charge, by the Leyden jar, is often a matter of great importance in the chemical applications of electricity. A jar, of the capacity above-mentioned, when dry, warm, and fully charged, should, after a lapse of ten minutes, give a spark at least half an inch in length to the ball of a discharging-rod, the ball being one-third of an inch in diameter.

The power of the jar is dependent on the amount of the coated surface, and the thinness of the glass.

The Electrical Battery.—This is an arrangement by which the metallic surfaces of the Leyden jar are greatly increased in size, and by which the intensity of the shock and discharge is multiplied to almost any extent desired. A number of Leyden jars, prepared in the usual manner, are placed in a box, which is lined with tin foil or other metallic coating. The vessels are placed in close contact, or are made to connect with each other externally by the interposition of metallic or coated partitions, and the inner coatings are made to communicate by means of metallic rods or chains, connected with the wires going from their interior. The whole is equivalent to a single large jar, and may be charged and discharged with equal facility. (Fig. 450.)

Fig. 450.



The hook, seen in the front of the box which contains the series, is attached to the metallic outer lining.

When the battery is to be used, it should be ascertained that all the outside coatings are in proper connection with each other, and that the inner surfaces communicate through their appropriate mountings and wires, and that no wires, threads, water, or other conducting substances extend in any way from the inner to the outer parts of the apparatus. No filamentous or pointed body, or projecting piece of metal, should be allowed to remain very near the battery while it is in operation. The battery is charged by connecting one of the wires or knobs which are in contact with the inner coating of the jars, by means of a chain or wire, with the prime or negative conductor of the electrical machine while it is in operation. It is both filled and discharged

in the same way as the Leyden jar, and all its operations are those of that vessel upon a greater scale.

During the charging of a battery, a diffusion of electricity sometimes takes place over that part of the uncoated glass, which is near the edge of the foil. This is not entirely removed upon the discharge of the coated part, but afterwards gradually returns to the coating and recharges the battery, often to a considerable extent. Hence, if after the discharge of a battery, it be left for a few minutes with the two coatings unconnected, it will, upon the application of the discharger, give a considerable spark. This, which is the *residual charge*, is discharged in the same way when the Leyden jar is used.

In order to know when a jar or battery is fully charged, the inner coating is brought in contact with the quadrant electroscope, the arc described by the repulsion of the needle of which shows the relative amount of electricity in the jar or battery. When the angle marked by the needle remains constant, or reaches to 45°, the jar is filled to its capacity.

When it is desired to cut off electric communication with other bodies, the object must be placed upon an insulated stool. The latter is nothing more than a common stool with strong legs of glass, which, being non-conductors, effect the insulation.

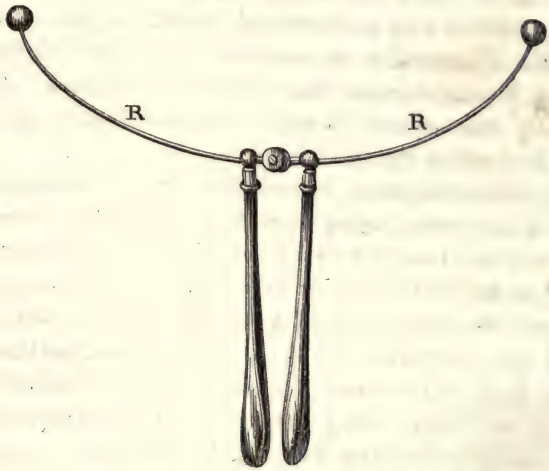
A plate of mica, or a piece of dry glass plate, laid across the top of a glass jar, will answer as an insulating plane. It should not be placed upon any conducting body, because of the influence it may receive through induction.

The Discharger.—A discharge between the oppositely electrified surfaces of the jar may be effected by bringing one hand in contact with the external coating, and touching the knob with a knuckle of the other. In this case the person receives a shock in his arms, and if the surfaces are large or well filled with electricity, he experiences a painful passage of this shock through the shoulders and chest. A battery ordinarily charged, should never be discharged in this way, as serious and even fatal results might follow.

The instrument shown in the figure is called a discharger, and is used to complete the circuit between the opposite coatings of both the jar and the battery. The rods R, R, are so united with a hinge that the balls may be made to come in contact with the

surfaces or to be removed from them by means of the insulating glass handles, which are attached to the legs. This arrangement

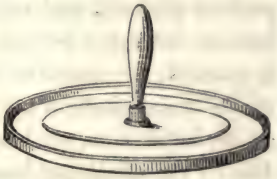
Fig. 451.



gives the power of discharging a jar of almost any size, by removing or approximating the handles. A very effectual and cheap discharger is made of a piece of thick wire, about twelve inches long, curved, and terminated by a bullet at each end.

The Electrophorus.—This important instrument, Fig. 452, may, in many cases, be made to take the place of the common electrical machine. A mixture of equal parts of common resin, shell-lac, and Venice turpentine, is melted and kept in a state of fusion at a temperature between 230° and 240° of Fahrenheit, until nearly all evolution of vapor has ceased and the fluid is quiet. It is allowed to cool to the point of thickening, and is then poured carefully, so as to avoid the formation of air-bubbles, into a circular metallic tray or dish, of about nine or twelve inches in diameter, and half an inch in depth. The resinous surface should be as even and as smooth as possible. A wooden box, or a receptacle made by placing upon a smooth board a wooden hoop, are less costly, and do not expose the resin

Fig. 452.



to the risk of cracking from the sudden contraction of the metal, which is apt to occur after its expansion by heat. Upon the smooth surface formed by the cooled mixture, is placed a metallic disk, or one of wood smoothly covered with tin foil, either of which is provided with an insulating handle of glass or sealing-wax, which is inserted in its centre above. This disk should be somewhat less in diameter than the surface of resin. The top has usually attached near its edge a wire terminating in a metallic ball, from which the spark is taken.

When this electrophorus is used, the cover is removed, and the surface of the resin having been dried and slightly warmed, is rubbed or wiped briskly with a piece of dry flannel, a silk handkerchief, or the fur of a cat or hare's foot. After excitation by this means, the cover is lifted by its handle—also dry—and is replaced upon the surface of the resin. A spark will then pass from the knob of the cover to the knuckle, or a metallic body held near it. Upon raising the cover again, another spark, of greater intensity than the first, will be received. A spark like the first will be emitted by the knob after replacing the cover, and again upon its withdrawal one similar in character to the second will be given off, and in this way the experiment may be repeated almost indefinitely, if the weather is favorable.

The action of the machine is explained in this manner. The negatively excited cake of resin acts inductively upon the electricity inherent in the cover, attracting and combining with its positive element, and repelling its negative one, which accumulates in the upper part of the cover. When the top of the cover is touched, the negative electricity escapes, and the positive remains in combination with the negative kind of the resin, as long as the latter is covered by the metallic plate. But, upon lifting this by the insulating handle, the positive excitement is in its turn set free, and given off in sparks from the knob. A similar succession of actions goes on for some time, and the instrument has been known to give sparks for weeks without being freshly excited.

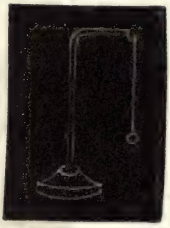
To obtain strong positive sparks, it is necessary to touch the cover, when on the resin, with a finger or other conducting body, and to remove it before raising the cover. To obtain the strongest negative sparks, the cover, when raised, should be discharged of

all its electricity, by touching with the hand, before it is again placed upon the surface of the rosin.

DETECTION OR MEASUREMENT OF ELECTRICITY.—It is an established fact that ordinary annealed glass and sealing-wax become respectively positively and negatively excited when rubbed with a piece of silk. It is equally well determined that an attraction exists between bodies in their natural state and electrized matter; that bodies, in a similar state of excitement, repel each other; and that, on the other hand, bodies oppositely electrized attract each other. Thus it is that we are enabled to apply tests which will distinguish the kind of electrical excitement shown by various substances.

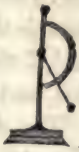
Instruments for this purpose are called *electroscopes*, the simplest form of which consists of a glass rod to which is fixed a thread of silk suspending a pith ball. If a piece of sealing-wax, excited by rubbing, is brought near this ball, the ball will be attracted to the sealing-wax, and after having touched it will be repelled. The ball, in the first instance, being attracted by the negative electricity of the wax, after having come in contact with it, becomes itself negatively electrized and is repelled. Any electrized substance brought near the ball will then attract it, if positively electrized, and repel it if in a negative state.

Fig. 453.



Henley's Quadrant Electrometer.—This instrument, Fig. 454, chiefly used to determine the amount of electricity present in the conductor and in the Leyden jar, consists of a semicircle of ivory or of wood covered with white paper, which is graduated into 180 degrees, and fixed at its base to a wooden column. In the centre of the semicircle there is a pin upon the column, from which a movable radius, terminated by a pith ball, is suspended. The column may be fixed in a hole in the conductor. Upon working the machine, the column and the ball being alike affected, the latter with its radius is repelled from the former, and by the amount of the divergence the force is exhibited in degrees. By means of this instrument, we are enabled to ascertain when a jar, or battery, in contact with the conductor, is sufficiently electri-

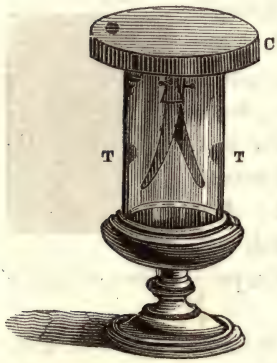
Fig. 454.



fied. During the accumulation in the inner coating, the electricity is retained forcibly by the attraction of the contiguous and oppositely electrified surface, and will not be given off to an insulated body, or one which is not in connection with the outer coating. But, in proportion as it ceases to be retained by this inductive action, and accumulates in the conductor, it raises the index of the electrometer, often to a considerable height. When a battery has received its greatest amount of charge, the ball seldom rises above 40° or 50°, as the tension of the electricity never equals that of a single jar, probably on account of the larger surface exposed to induction.

Bennet's Electrometer.—This instrument, more properly called an electroscope, as it detects rather than measures electricity, is exceedingly delicate in its indications. It consists in part of a glass cylinder, which may be similar in form to the one shown in the drawing. A circular brass cap C, covers tightly the vessel, and to its centre is attached a metallic rod, enclosed in a glass tube, which is well varnished with shell-lac, and having attached to its ends two slender strips of gold leaf hanging parallel to each other. Two strips of tin foil T T, are pasted upon the inside of the glass, with their upper ends a little above the level of the depending extremities of gold leaf, and their lower ends connected with the metallic bottom of the glass cylinder. When an electrified body is made to approach the cap of the electrometer, the gold leaves will diverge, and if the excitement be sufficiently powerful, will touch the tin foil, and then return to their former state of rest.

Fig. 455.



The delicacy of Bennet's electrometer is much increased by the addition of two metallic disks, one having its centre soldered to the side of the cap of the instrument, being in a perpendicular position, and the other being attached to a rod which is connected with the metallic foot of the instrument by a hinge, so that it may be placed parallel to the other disk, and so near as almost to touch it without actually doing so. The presence of elec-

tricity in the metallic cap and its disk, *induces* the opposite kind in the contiguous metal, which is then to be removed a few inches from its former position. As this disk is connected with the base of the instrument, and of course with the tin foil upon the inside of the glass, that becomes also oppositely electrified from the cap, the connected gold leaves of which diverge to a much greater degree than in the simple instrument. This is called the *condensing electrometer.*

Bennet's electrometer is the one in most common use, and many circumstances of interest in reference to its employment are worthy of note, particularly those connected with the means of ascertaining the kind of electricity which causes its gold leaves to diverge.

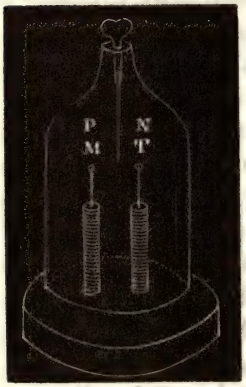
If an insulated conducting body containing electricity, such as the prime conductor of the electrical machine, is made to approach or to touch the cap of the electrometer, the leaves diverge to a greater or less degree, in proportion to the tension of the electricity in the body, and remain separated, gradually returning to their former position as the influence passes off. In examining the condition of a body supposed to be highly electrified, care must be taken not to make it approach the cap too rapidly, as the result of a sudden and powerful communication of the agent is very often the immediate separation and tearing of the gold leaves. When a non-conducting body, electrically excited,—a piece of sealing-wax, for instance,—is brought near to or in contact with the top of the instrument, the same divergence takes place; but it is temporary, as upon the withdrawal of the body the leaves come together again. To make their separation as lasting as in the former case, it is necessary either to allow the body to remain for a time upon the cap, or to rub it over its surface, so that it may communicate its electricity from a number of points. So far, the electricity of either kind, imparted to the cap, has been that of *conduction.* But if the electrified body be held so near to the cap, as just to cause the divergence of the leaves, that divergence will diminish gradually until the leaves finally collapse. If now the body be removed to such a distance that it can scarcely affect the leaves, they, after coming together, will often gradually diverge as before. This second separation is caused by *induction*, and when it occurs, the opposite kind of

electricity to that existing in the body will be found to be present in the cap and leaves. The same effect is produced by touching the cap with the hand, while the leaves are diverging from the electricity of the excited body, by removing the hand after the collapse occasioned by its first contact, and by then withdrawing the electrified body, as before, to a greater distance from the cap.

It is well known that a piece of sealing-wax rubbed with warm flannel becomes negatively electrified, and that a glass tube rubbed with a silk handkerchief becomes positively affected. These facts present us with the means of determining the kind of electricity which is transferred to the cap and leaves of Bennet's electroscope. If, after the leaves have been made to diverge by the approximation to the cap of an excited body, the presence upon the top of a piece of rubbed sealing-wax makes the divergence greater, the electricity in the body is negative. If, however, the leaves approach each other slowly, or collapse at once, the electricity is more or less positive. In the same way, a warm tube of glass, rubbed with a silk handkerchief, will increase the separation of the positively electrified leaves, and diminish or annul it when they are negatively excited.

The Voltaic Pile Electroscope.—This was invented by Bohnenberg. It consists of two dry voltaic piles, made of layers of paper, tinned on one side, and covered with a thin coat of peroxide of manganese on the other. The manganese is made to adhere by forming it into a paste with milk and starch. The paper thus prepared is cut into disks and made into piles, care being taken to observe the proper order, the tin and manganese being always in contact. The piles are fixed on a stand about four inches apart, and each is terminated by a metal ball of the same diameter as the disks. The order of the disks is so arranged that the upper poles of the two piles are respectively positive and negative; the manganese being the positive element. The whole is covered by a bell glass, through the top of which is

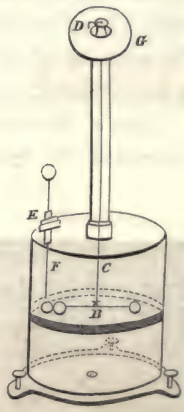
Fig. 456.



inserted a metal wire having attached to its lower end a piece of gold leaf, which hangs *exactly* between the poles of the two piles. This forms a very sensitive electroscope, and indicates the kind as well as presence of the electrical excitement.

Coulomb's Electrometer.—All the instruments previously described indicate the presence of electricity, but afford little idea of its quantity. Coulomb's torsion balance gives us a means of measuring it with approximate exactness; or rather of comparing the amount of it found in one body with that existing in others, or in the same body at different times. This instrument, as represented in Fig. 457, consists of a slender beam, or thread, of shell-lac *B*, having a gilt pith ball attached to one end, and a little vane of paper to the other, and suspended at its centre by a fine metallic wire, or, what is better, a delicate filament of spun glass. This ascends in a cylindrical or square frame of glass, and its upper end terminates in a key *D*, furnished with an index, the whole being capable of moving easily in the centre of the circle *G*, which is graduated into 360°. A rod of shell-lac *F*, is inserted in the hole *E*, and is prevented from falling down into the glass cylinder which surrounds the whole arrangement, by a stop at *E*. This rod terminates in a gilded ball, which is called *the carrier ball*, as it is used to convey to the electrometer proper, the electricity of the excited body. When this instrument is to be used, the rod *F* is brought into contact with the excited body; its ball acquires some of the electricity, and upon being placed in the cage, it gives a part of it to the ball of the lac beam. This having now the same kind of electricity, is repelled from the ball of the rod, and describes a certain angle to its former position, which it retains until it loses its electricity. To measure the amount of fluid thus acquired, the key *D*, to which the glass thread is fastened, must be turned around, until by the torsion or twisting of the latter, the ball of *B* is made to come in contact with that of *F*. The number of degrees described by the index, which is attached to the revolving key *D*, gives an approximation to the proportion

Fig. 457.



of electricity derived from the contact of the ball of *F* with the electrified body.

A more simple form of this electrometer, and the one ordinarily described, consists of a lac needle with a gilt ball at each end, suspended by means of a fine untwisted thread of raw silk, which is fixed at top to a micrometer, by means of which it can be turned around any number of degrees required. The whole is encased in a glass vase or cylinder, with a tightly-fitting top of glass, through a hole in the centre of which the silk passes, the micrometer being above. Upon the level of the suspended needle, a hole, drilled through the sides of the glass, encloses a wire having a metallic ball at either end, the inner one being nearly in contact with one of the pith balls. The excited body is made to approach the outer ball, and, as in the instrument before described, the movable knob separates from the other, and the quantity of electricity is proportional to the distance to which it is driven off.

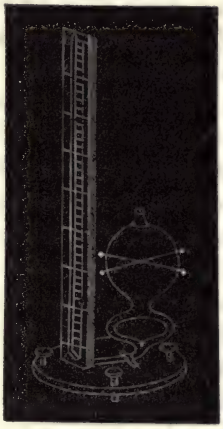
Lane's Discharging Electrometer.—This instrument is for indicating the intensity of a charged jar or battery. Its construction is shown in Fig. 458. A glass arm, fitted in the cover of the Leyden jar, has a hole in its upper end, on a line with the ball of the jar, through which passes a metallic rod, terminated at each end with a ball similar to the one of the jar. The outer ball communicates by a chain with the external coating of the jar, and the inner is advanced to the ball of the jar until near enough to receive the spark. The intensity of the charge is shown by the distance at which the discharge takes place. Of course, in the comparison of batteries, the result is only relative when made under a like condition of the atmosphere.

Fig. 458.

Calorific Electrometer.—"The effect of the electrical discharge on metallic bodies is to raise their temperature to a greater or less degree, and, in many instances, to render metallic wires red-hot, and to dissipate them in a shower of melted globules. The fusion of wire has accordingly been resorted to as a measure of

the force and extent of electrical accumulations on coated glass. Independent of the uncertainty and tediousness of this method, it is quite inapplicable for nice investigations. The calorific electrometer, whilst it avoids all destruction of the metal, indicates at the same time the comparative heating effect of the discharge, and admits of an accurate estimation of the force in operation. It consists of an air-thermometer, Fig. 459, having a fine wire of platinum passed air-tight across its bulb, which is screwed also air-tight on a small open vessel containing a colored liquid, and soldered to the extremity of a bent glass tube. The long vertical leg of this tube is supported by a graduated scale of inches and tenths, on a convenient foot, the lower part of which is marked zero, at the point where the colored liquid in the short leg finds its level. There is a small screw-valve on the top of the ball, to admit of an opening with the external air, so as to adjust the fluid to zero.

Fig. 459.

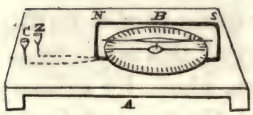


"When an electrical accumulation from a jar or battery is passed through the wire in the ball, the temperature of the wire is more or less raised, which causes the air to expand and press the colored fluid up in the long leg, the altitude being measured on the graduated scale. In this way, a comparative numerical value of the heating effect of the discharge may be arrived at; and it is found that the height to which the fluid rises in the long leg is, *cæteris paribus*, as the square of the quantity of electricity discharged through the wire. The delicacy of this electrometer will depend on the size of the platinum wire, which, for ordinary purposes, may be from one-fiftieth to the $\frac{1}{100}$th of an inch in diameter, and about three inches in length, corresponding with the diameter of the ball of the thermometer."

The Galvanometer.—This is an instrument for detecting the electricity developed by chemical or galvanic action. If a common magnetic needle, supported upon its pivot, be placed directly *under* and parallel to a wire which is connected with the poles of a galvanic circuit, so that the positive fluid will pass through the

wire from the north to the south, it will, during the passage of the current, leave its position in the magnetic meridian, and, after a few oscillations, assume one nearly or quite at right angles to it, its northern end or *austral* pole pointing to the *east*, or to some point between it and the north. Precisely the same effect will be produced if the needle is placed *over* the wire, and if the direction of the current is reversed. But the northern end will be turned towards the *west*, if the current is passed from the north to the south while the wire is under it, and also in the same direction if the wire, again placed over it, transmits the fluid from the south to the north. The needle always returns to its former position immediately after disconnecting the wire. The power possessed by a galvanic current of influencing the magnet, may be increased to almost any extent, by passing it through a number of wires, or a coil made of a single one, so as to make the action of the whole equivalent to the sum of the actions of all its spires. This can be done most effectually by bending a long wire, covered with cotton or silk, to prevent the lateral escape of the current, into the form of a rectangle. The needle is supported parallel to, and between its horizontal branches, and it is obvious that it will be similarly affected by each part of the coil, in whatever position its wires may be; for, as before stated, a current passing above it from the north to the south, and one passing below from the south to the north, cause it to deflect in the same direction. This instrument is the galvanometer, or the "*electro-magnetic multiplier*," of Schweigger. By its use we can detect traces of electricity much too minute to act on the gold-leaf electrometer; but its chief applications are to the discovery of delicate galvanic currents, and to the determination of their direction.

Fig. 460.

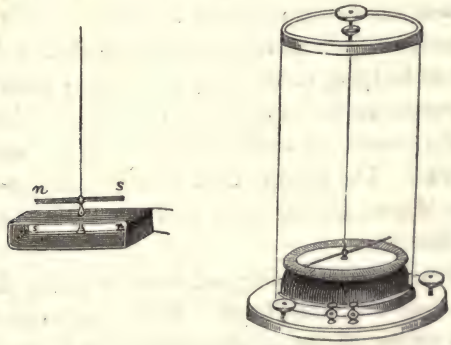


As shown in the figure, 460, it consists of the coil of covered copper wire N B S, containing usually about twenty convolutions, of which the extremities are connected with the cups C Z. A card, graduated into 360°, is fixed to the board A, so that a line drawn between the numbers 360 and 180, coincides with the direction of the centre of the coil. Above this is placed a delicate magnetic needle, supported on a pivot. The coil is placed with its long axis in the magnetic meridian. If

any source of feeble electricity is now connected with the cups, the current from it will pass through the coil, and the magnet will move to the east or west, according to the direction of the fluid. The intensity of the influence is estimated in degrees, by comparing the position of the utmost divergence of the needle with the number under it on the card. The delicacy of this instrument depends in a great measure upon the number of convolutions of wire. Thus, if all other circumstances are favorable, it may be supposed that one consisting of one hundred turns will detect an amount of electricity which is only one-fifth as great as that shown by the one with twenty convolutions.

The Astatic Galvanometer.—The sensibility of the common galvanoscope may be almost indefinitely increased by connecting the magnetic needle immovably with another one placed above the rectangular coil of wire, but parallel, and opposed in the direction of its poles to the first. They are fastened by their centres to a common axis, which revolves freely in an aperture of the upper branch of the coil. This axis is suspended by a fibre of silk to the upper part of the glass or other vessel in which the whole is encased, and it penetrates a graduated card, placed under the upper needle. This arrangement makes the needle a

Fig. 461.



balance of torsion, the movements of which are compared with the degrees marked upon the card, in the same way as in the simple multiplier. Terrestrial magnetism has scarcely any effect upon this system of needles, and would have none at all if both possessed an equal amount of magnetic power, the tendency of the

one to assume its position in the meridian being in that case entirely counteracted by the reversed direction of the other. By a reference to the statements at the head of this article, it will be seen that a current passed through the coil, in either direction, will have the same effect upon both needles. Fig. 461 represents two of the many forms of Nobili's galvanometer. It is called *astatic* because it is unaffected, or nearly so, by the magnetism of the earth.

As these instruments are used not only to detect currents, but also to ascertain the directions in which they pass through the wires, it is important to impress upon the mind the movements of the needles which indicate that one or other extremities of the coil is in connection with the positive or negative electric poles. A simple aid to the memory is to suppose that a current is passing around the middle of a watch, from the handle over the face, and is returning back to its place of origin. The minute-hand, if pointing to the hour twelve, which is usually placed next to the handle, may be supposed to represent the northern half of the needle. It would then move around in its usual direction towards the figure three. If the current were passed around the back of the watch from the handle, and returned to the face, the hand would move backwards towards the figure nine. Ampere has devised the following formula, which is still better calculated to impress the direction of the deviations upon the memory. "Let any one identify himself with the current, or let him suppose himself to be lying in the direction of the positive current, his head representing the copper, and his feet the zinc plate, and looking at the needle, its north pole will always move towards the right hand." The person must, however, suppose himself to be lying over the needle, his head and its north pole being both in the same direction.

The needles, notwithstanding all care to make them astatic, will vary in their magnetic force. Nobili suggests, in order to equalize the action of the needles, that after having discovered which of the poles of the needles are most highly magnetized, to abstract a portion of the magnetism by touching them lightly with the opposite pole of a weak magnet. As the sensibility of the apparatus depends upon the needles having only so much directive force as to keep them in a fixed position, it is necessary

to adjust them carefully, so that they may be affected by the feeblest current.

After the direction of the current is once ascertained in the instrument, to avoid delay and the annoyance of repeating the operation, it is best to mark it upon the card.

Differential Galvanometer.—An instrument for comparing the force of two currents. It is made by forming simultaneously into a coil *two* wires exactly similar in diameter, length, and every respect; and arranging the needles so that when two equal and opposite currents are passed through the wires they will exactly neutralize each other, and bring the index to 0°. But when unequal currents are compared, the needles will indicate the direction of the currents and their relative intensity.

Galvanometers of this sort differ only in the length and size of the insulated wires, according to the purposes to which they are to be applied. Care is requisite in winding the coils to have the wires perfectly insulated. This is attained by gimping them with thick silk, and interposing a coat of shell-lac between each successive layer on the coil. In the case of galvanometers, it is important not to subject them to currents too powerful for their capacity, as the action of the needles is apt to be impaired by a diminution, and sometimes even of an inversion of their magnetism.

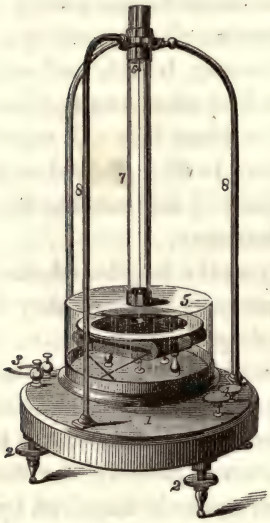
Weygandt's Galvanometer.—The principal novelty of this apparatus, Fig. 462, is the construction of the pole-changer, which gives great facility in working, and allows the coil and divided circle to be turned freely around without altering the position of the pole-changer or disturbing the needle.

This instrument, as described in the Franklin Institute Journal, No. 356, rests upon a flat, circular wooden stand (1), about nine inches in diameter, which is supported by three levelling screws (2). On one side of the stand are the two binding-screws (3), for the reception of the wires from the thermo-pile, or metals to be experimented upon;—the wires running from them to the keys of the pole-changer, which is situated diametrically opposite to the binding-screws on the stand (1).

From the centre of this stand, rises the brass centre, upon which the circular glass box (5), containing the coil and graduated circle, turns with a very steady motion. The two needles

are suspended by a human hair from a hook (6) at the top of the instrument, which is arranged so as to be very nicely adjusted for the twist and for its height in the coil.

Fig. 462.



The coil, needles, and graduated circle, are enclosed in a glass box, the plate on the top of which has a small hole in the centre through which the suspending hair passes; the hair being protected by a glass tube (7), the top of which is supported by the long brass standards (8), which carry the suspending hook. By this arrangement the graduated circle can be read through a plane flat glass, instead of through the side of the glass cylinder, as frequently constructed. The inner wire of the coil comes down to a brass ring, which is fixed to the underside of the bottom of the revolving-box. Concentric with this ring, and in the same plane, at the distance of quarter of an inch, is another brass ring which is connected through the axis with the wire from the outside of the coil. These two rings thus form the extremities of the coil, and the pole-changer plays between them. The wires from the binding-screws are attached to two brass slips, which terminate in pieces pressed by a spring against the inner ring, so that when the pieces are in their normal position, the current from the binding-screws passes through the short space of ring between them, and does not go through the coil; but when either of the pieces is withdrawn from the inside ring, and pressed against the outside ring, the current passes through the coil, and by altering their position again, bringing that one which was against the inside ring in contact with the outside ring, and that which was in contact with the outside against the inside ring, the direction of the current is changed, and the needle deflected in the opposite direction. If the stand is placed upon the table

in a position which is convenient for the operator, with the keys of the pole-changer near his right hand, the coil and graduated circle can be placed in any position without interfering with the circuit, as some part of the brass ring must always be opposite to the pole-changer.

Each key of the pole-changer works like the writing key of a telegraph; that is, it is depressed by the finger, and returns to its position by the spring attached to it. By means of the fore-finger and second finger depressing the keys alternately, the direction of the current can be changed six or eight times in a second, and the motion being in a vertical plane, is little liable to affect the adjustment of the instrument. The operator has, therefore, very great facility in bringing the needle to rest by changing the circuit, and thus checking the vibrations, which enables him to make a great many more observations in a short space of time than with any other instrument known.

This instrument is remarkable for its delicacy, as was confirmed by the following tests.

Two pieces of zinc and bismuth, each about the size of an ordinary type, being held in the fingers of the operator, the free ends touching the binding-screws, produced an instantaneous and steady deflection of 175°.

With a small magnet, weighing about half an ounce, a deflexion of 95° was produced, at the moment of induction, by introducing the magnet into the coil.

Two wires of zinc and copper, one-twentieth of an inch in diameter, and dipped one-fifteenth of an inch into a single drop of Schuylkill water, gave an instant deflexion of 12°.

With a small Melloni thermo-multiplier of twenty pairs, the heat from the face of one of the observers, at a distance of eight feet, gave a deflexion of 68°.

The needle can be brought to rest, after a deflexion of 90°, in a very few seconds, by alternating the current by means of the pole-changers.

The needles are remarkably astatic, having a very small directive power, and standing steadily in an east and west position, with a slight trouble in setting them. Mr. Weygandt mentions that the power of the needles was balanced by rubbing the stronger one lightly upon an oil-stone, which appeared to weaken

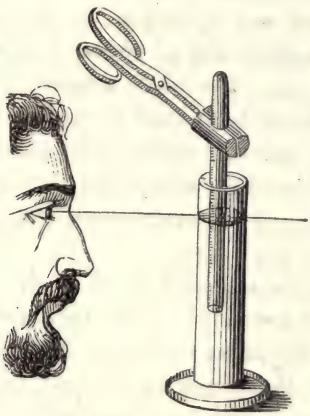
without removing any sensible part of its weight. Altogether, the instrument is very remarkable for its high finish, extreme delicacy, and great convenience in use, the arrangement of the pole-changers enabling the observer to make many observations in a short time, by the great ease in bringing the needle to rest by changing the current rapidly.

Applications of Electricity.—Electricity proper has its most general application in the chemical analysis of gaseous mixtures, being the convenient and efficient means by which they are exploded and decomposed. It is employed in connection with the eudiometer, an instrument, as its name indicates, chiefly intended for determining the purity of the air, but by means of which other gases, containing carbon and hydrogen, are occasionally examined. These latter are made to unite explosively, in it, with oxygen; while in the examination of the atmosphere, the explosion of hydrogen with its constituent oxygen, and the consequent production of water, and diminution of volume, enable the chemist to determine the proportion of its ingredients. It would be foreign to our purpose to give a full description of all the applications of eudiometry; but a short account of the means most commonly employed, particularly in reference to the proper mode of applying the electric spark, will scarcely be at variance with the practical nature of this work.

The Common Eudiometer is a short tube of thick glass, having one end closed. This tube is graduated, and near its closed extremity, two stout wires of platinum, or other metal, intended for the transmission of the spark, are inserted in the opposite sides, their ends inside of the tube being a short distance apart. The other end of the tube serves for the introduction and escape of the gas, and it remains constantly immersed in the liquid over which the experiment is made, the tube being supported in a perpendicular position. The gas to be subject to the spark is generally such a mixture as will inflame explosively at once, though sometimes a gradual combination of some of its elements is effected by a long-continued succession of sparks. The tube, being filled with water or mercury, may be placed over the trough; or, for the purpose of more accurately determining the level of the gas in the way about to be described, it should be supported over a glass vessel containing the proper liquid. The gases are

then successively introduced into it, in the proper proportions, after the manner heretofore described. To determine their volumes with the utmost degree of accuracy, it is necessary to support the tube by a forceps or a cork-lined clamp, as represented in the figure, and not between the fingers, so that their

Fig. 463.



temperature and volume shall not be increased by the heat of the hand. To insure that the gas be submitted to no more pressure than that of the atmosphere, the eudiometer should be raised in such a manner that the interior level of the liquid contained in it, shall be exactly at the same height as that of the liquid in the vessel outside. In order to secure this, it is necessary that the eye of the observer be in the same plane as the two levels of the liquid, and that the line of the liquids in direct contact with the glass inside and outside of the tube, be not taken as the proper standard. It must be recollected that,—as the edge of a surface of water, in contact with the glass, is elevated above its true level by capillarity, and that of mercury in the same circumstances is depressed,—the lower line in the former case, and the upper one in the latter, will give the true position of the main surfaces. The exterior of the tube is now wiped clean, so that no mercury or water in contact with the wires, can conduct off the electricity. The tube, kept upright, should then be clasped firmly in the hand by its middle, and its lower end, still under water, should be closed with slight force by the thumb or a finger of the unoccu-

pied hand. This permits the descent of the fluid, which is driven out by the force of the explosion, while it does not allow its too sudden return upon the subsequent contraction of the gaseous contents of the tube, or the escape of any of the latter.

In using the eudiometer, we must take into account the relative degree of explosibility of different mixtures. Thus a mixture of oxygen and carbonic oxide expands when inflamed, much less than one of oxygen and hydrogen or olefiant gas. A large quantity of any mixture will of course increase in bulk much more than a small one. The whole quantity of gas contained at first in the tube, should be at least so small, that after expansion it shall not occupy quite the whole of the eudiometer. No more gas should be introduced for detonation than will occupy a sixth of its capacity at common temperatures, and generally it will be advisable to employ much less.

The spark which is intended to effect the detonation or slow union of the gases contained in the tube, may be derived from the electrophorus, the prime conductor of the electrical machine, or the Leyden jar, the power of the last two being of course greater, in the order in which we have spoken of them, than that of the first. When the electrophorus is employed, one of the wires upon the side of the eudiometer is placed in connection with a finger of an assistant, or with a metallic chain, the other end of which hangs in the trough or vessel over which the tube is supported. The ball of an excited electrophorus is then brought near to the other wire, and the spark obtained from it, passing from wire to wire through the interior of the tube, inflames the mixture, if it be of sufficient intensity, and if all the other circumstances are favorable. The ball upon the conductor of the electrical machine may, in the same way, be made to approach one of the wires, with usually a more powerful effect. The employment of the electrical machine is particularly advantageous when it is desired to pass a succession of sparks for a considerable time through the mixture, for the purpose of effecting a gradual combustion or combination of the gases contained in the tube. The use of the Leyden jar is equally convenient for a single contact, and much more apt to be attended with success, on account of the greater size and force of the spark. One of the wires may be connected with the external coating of the jar,

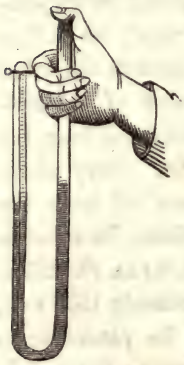
by means of a chain or hooked wire, and a discharger or other conductor, applied at one end to the ball of the vial, may be brought near the other wire. When other means of connection are not at hand, the operator, at the risk of receiving an unpleasant shock, may grasp the jar in his hand, and apply its ball to one wire of the eudiometer, while he touches a finger of the other hand to the opposite wire. To insure the explosion of the mixture, a spark of the largest size that can be obtained from the electrical instrument, should be passed through it. Very often, although a sufficient amount of electricity is given off from the conductor of the electrophorus or electrical machine, its effect is lessened by its communication from wire to wire, as an electrical brush, or in a succession of small sparks. To remedy this evil, a ball, half an inch or more in diameter, should be placed upon the outer extremity of that wire which is to receive the spark, and the latter should always be given off from the surface of a ball of considerable size.

The wires of the eudiometer must be firmly fitted in their places, and the openings in the glass through which they enter should be hermetically closed around them. Before filling the tube with gas, it must also be ascertained that they are perfectly insulated. When the detonation is effected over water, a film of it is apt to adhere to the glass and wires, both internally and externally, which, by its conducting power, sometimes diminishes the force of the spark, or intercepts it entirely. To prevent this, the outside of the tube and wires must be wiped as dry as possible before applying the conductor. The top of the tube should be gently tapped so as to shake off any particles of moisture adhering to it within. The perfect transmission of a large spark is only secured by the presence of the balls upon the ends of the wire and discharger, as before described.

Ure's Eudiometer.—Analysis of gases by explosion is much more conveniently performed by means of Dr. Ure's syphon eudiometer, shown in Fig. 464. It differs from the other eudiometer in being curved like the letter U; but, like it, it has the part intended to contain the gaseous mixture graduated and pierced by two platinum wires. It is usually about twenty inches in length, and the third of an inch in internal diameter. This instrument, like the other, may be used for the analysis of va-

rious gases over either water or mercury, but it is applied chiefly to that of atmospheric air over the latter liquid: and we will confine ourselves to a short account of this employment of it. When about to be used for an examination of the atmosphere, it is filled with mercury, and the required amount of air is introduced into the open end, which is inverted over the trough, as in the case of the use of the other form of the tube. This end is then tightly closed with the finger, and the tube is turned slowly so as to admit the air into the graduated extremity. The instrument is then held upright, and the amount of air introduced is read off by looking at the scale, after subjecting it to atmospheric pressure by displacing, with a stick thrust in, that portion of mercury which is above the level of that in the graduated limb. This having been accurately done, the open part is again filled with mercury, closed with the finger, inverted into the liquid, and an amount of pure hydrogen is introduced equal, as nearly as can be guessed, to half the volume of the air. The quantity of hydrogen added is then accurately estimated by returning the eudiometer to the erect position, equalizing the surface of the mercury as before, and reading off its level. The instrument is then held in the way represented in the figure, the thumb firmly closing its aperture, and the knuckle of the forefinger touching the nearer platinum wire. The explosion is produced by the aid of the electrophorus, prime conductor, or charged jar, as before described, the violence of the expansion being moderated by the spring-like action of the air contained in the open limb. The level of the mercury is again equalized by pouring into the open side enough to produce that result, and the volume of the gaseous mixture is then finally read off.

Fig. 464.



The loss in volume of the mixture, which is produced by the explosion, gives, by a very simple process, the amount of oxygen originally contained in the air. As hydrogen unites with oxygen to form water in the proportion by measure of two to one, one-third of the diminution must be due to the oxygen of the air introduced. Thus, if 100 measures of air and 50 of hydrogen

have been introduced, and if the mixture contain only 87 measures after explosion, the diminution has been that of 63 measures. One-third of this loss is equal to 21 measures, which represents the amount of oxygen in the 100 measures of the air first introduced.

The same precautions are to be observed in manipulating with this instrument as directed for the common eudiometer.

ELECTRICITY DEVELOPED BY GALVANIC ACTION.—All the forms of apparatus for the purpose of producing a continuous electrical current, are called galvanic circuits, and those in common use consist of two metals, one more oxidable than the other, and of a liquid, which, by its action upon the readily oxidized or active metal causes the development of the influence. The old voltaic pile and the crown of cups are the most simple examples of galvanic apparatus. The former consists of a series of disks of zinc and copper, platinum or silver, arranged in a column, each piece of different metal having placed between it and its neighbor a disk of cloth, or paper, steeped in some liquid which acts chemically upon the zinc. The crown of cups is differently arranged, but upon the same principle. A number of cups are placed in row or circle, each one containing an exciting liquid, such as dilute sulphuric acid, and a plate of zinc, and one of the inactive metal. The zinc of one cup is connected by a wire with the copper or other metal of the next cup, and the zinc of that is also connected with the copper of the one beyond it. The two external plates of both kinds of series have wires soldered to them, which are called *the poles*. In this way a communication exists between all the parts of the series, directly between the alternate plates of the different cups, and indirectly through the liquid between those in the same cup. A simple circuit, as exhibited by the most elementary form of either of these arrangements, represents in miniature all the other kinds of voltaic apparatus employed. Thus, if a single cup be used, containing a plate of zinc and one of copper, immersed in dilute acid, and having wires attached to them, the voltaic current is supposed to be developed upon the surface of the zinc, along with its partial solution and the evolution of hydrogen, to pass through the liquid to the copper, and to be conducted through that metal to the end of its wire, which forms the *anode* or positive pole. The end

of the wire attached to the zinc is the *kathode* or negative pole. When these poles are placed in contact with each other, or with a conductor of the fluid, the electricity originally developed upon the surface of the zinc returns to it from the positive wire through the negative one; and if the current be sufficiently powerful, the various phenomena of voltaic light, heat, electro-magnetism, chemical decomposition and action on the living body, are capable of being exhibited during this passage from pole to pole.

In most of the forms of compound circuits, where a number of pairs of plates are arranged together in a battery, the wire attached to the terminal zinc plate becomes the positive pole, and that of the last copper plate the negative one. This arises from the fact that in these arrangements the last two plates are actually superfluous, not being so much producers of the galvanic fluid, as conductors of that which has been generated in the intermediate parts of the apparatus.

The more oxidable of the metals should form a readily soluble salt with the exciting liquid. If both metals are easily acted upon by the liquid, the electrical current produced by one will be overcome in proportion to the action of the liquid on the other. So that the most power will be obtained by having one metal that is easily acted upon and another that will remain unchanged in the liquid. The metal dissolved is always the positive metal, and the unchanged metal the negative element. Thus, in an acid solution, silver is positive to platina and negative to zinc.

The following table of substances shows their electrical relation to each other in sulphuric acid, commencing with the most positive, and each element being respectively positive and negative to those that precede and follow it.

Potassium,	Bismuth,
Barium,	Nickel,
Zinc,	Silver,
Cadmium,	Antimony,
Tin,	Palladium,
Iron,	Gold,
Lead,	Charcoal,
Copper,	Platinum.

The conducting power of bodies is different. Fluids are generally imperfect conductors; the metals and carbon are the best.

Some of the metals are better conductors than others; the relative conducting power of eight of them, is as follows:

Silver, ...	100	Platinum, ...	20
Copper, ...	100	Iron, ...	20
Gold, ...	67	Tin, ...	17
Zinc, ...	33	Lead, ...	10

The efficiency of a battery, as regards intensity and quantity, depends upon the amount of surface of the positive metal acted upon, the distance between the positive and negative elements, the purity of the materials, the size and length of the connections, the temperature of the atmosphere, and the good condition of all the parts of the battery, and complete connections.

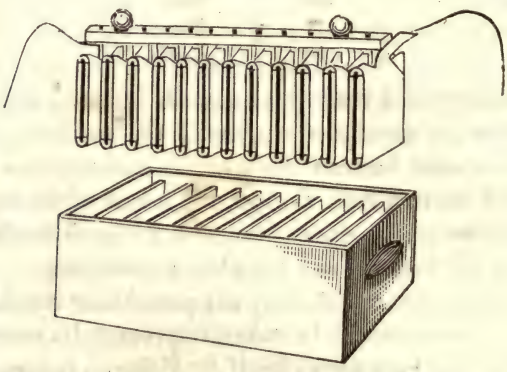
In constructing batteries, only the purest zinc should be used; and especial care should be taken to prevent its contamination with tin, which always shows itself by rising in flocculent masses to the surface of the solution.

To prevent local action in the batteries, which is occasioned by impurities in the zinc, the zinc should be amalgamated by first dipping it in chloro-hydric or sulphuric acid, and then quickly immersing in mercury, of which they should be made to absorb as much as possible. The excess of mercury is removed with a cloth, and the zinc well rinsed with water. Two and one quarter ounces of mercury will amalgamate a square foot of zinc surface. When batteries are not in use, all the parts should be removed from the vessels containing the liquids, well washed, and kept covered from the dust.

Wollaston's Battery.—This is the very best of the old forms of the voltaic battery. It consists, as shown in Fig. 465, of a number of zinc and copper plates, the latter entirely encircling the former except at the edges, and the two metals being kept apart by pieces of cork or wood. Each plate of zinc is soldered to the one of copper which is before it in the series, and the whole arrangement is screwed to a bar of dry mahogany, which permits its elevation from or depression into the acid. This is contained in an earthenware trough, divided by partitions into compartments, each one of which receives a single pair. The exciting liquid is made of a mixture of 100 parts by measure of water, 2½ parts of sulphuric acid, and 2 parts of strong nitric acid. In the same manner that the shock of the Leyden jar is

increased by combining it with others in a battery, the power of this apparatus can be multiplied to any desired extent, by uniting

Fig. 465.



it by means of strips of copper, passing from the zinc of one instrument to the copper of another, with any desired number of similar batteries.

The chief objection to the use of this and like forms of apparatus is what is called the *local action*, which, in it, is very great, and which gives rise to a rapid diminution of power and corrosion of the zinc.

The bubbles of hydrogen given off from its surface, adhere to the zinc, preventing perfect contact with the exciting fluid; some of the electricity is dissipated by the escaping gas, and the sulphate of zinc which is formed, is in part reduced to the metallic state, in a crust upon the surface of the copper. All of these circumstances form serious objections to the use of this battery where a long-continued action is desired.

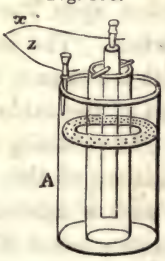
When common zinc is exposed to dilute sulphuric acid, it is rapidly dissolved, and this solution and loss of material in the common batteries are excessive and entirely disproportional to the amount of galvanic fluid given off. This, which is the *local action*, is supposed to arise from a number of little voltaic circles being formed by the presence in the zinc of particles of plumbago, and of other metals which excite the rapid erosion of parts of its surface. This evil can only be prevented, as before directed, by carefully *amalgamating* the surfaces of the zinc plate.

A single pair of Wollaston's battery is very efficient in the production of the phenomena which are due to the evolution of a *quantity* of electricity, such as ignition and deflagration on a small scale, the deflection of the magnetic needle, and the various electro-magnetic experiments. Its *intensity* or electro-chemical power is very much increased, as before stated, by combining it with other similar arrangements.

The plates of the old form of voltaic apparatus should be removed from the acid, and washed with water after the completion of each experiment, or if they are permanently connected with the trough, the acid in it should be poured out, and reserved for future operations. In Wollaston's battery, the plates are taken out by elevating the mahogany bar to which they are attached, and freed from acid and metallic deposit by washing with water, and are then either suspended over the trough by a cord attached to a support above, or are placed upon a tile or old table until their next employment. As the acid solution soon becomes unfit for use from the large amount of sulphate of zinc dissolved in it, it must be removed after reaching a certain point of saturation. The best evidences of the cleanliness and perfect connection of the surfaces, and of the activity of the liquor, are afforded by the constant bubbling up of hydrogen during the action, and by the ordinary voltaic phenomena exhibited at the poles.

Daniell's Constant Battery.—This is a far better form of apparatus than the one last described, and has the advantage over it of being comparatively permanent in its action. The local action being obviated by the amalgamation of the zinc, it is of course much more applicable to those purposes of electro-chemical examination in which long continued and uniform transmission of the fluid through a body is desired. In its simplest form, it consists of a copper cylinder A, 3 or 4 inches in diameter, and from 6 to 18 inches in height, containing in its interior a cell of porous earthenware or of animal membrane, within which is suspended a rod of zinc, three-quarters of an inch in diameter, which has been carefully amalgamated by rubbing its surface

Fig. 466.



with mercury by means of a cloth previously dipped in dilute sulphuric acid. The earthen cell or membrane containing the zinc is filled with a mixture of one part by measure of sulphuric acid and 8 parts of water, and the space between it and the outer copper cylinder contains a saturated solution of sulphate of copper, the surface of which should be upon the same level as that of the solution within the cell. The solution of blue vitriol is prepared by pouring boiling water over an excess of crystals of the salt, and stirring constantly until it is saturated.

To this solution, a little sulphuric acid, never amounting to more than one-tenth part by measure, of the whole, should be added. In order that this liquor be kept concentrated, a little perforated copper shelf, seen in the figure, is usually placed upon the inside of the cylinder, within an inch or two of the top. This is intended to contain a supply of crystals of the sulphate. They are placed at the upper part of the liquid, because that portion becomes exhausted first, and because the saturated solution of the crystals in its passage downwards diffuses itself equably. In the absence of the shelf, a strong bag of loose texture, or a network of copper wire attached to the top of the cylinder, may be used to contain the crystals.

Attached to each metal of Daniell's battery is a binding-screw to form connections. When wires are held in each of these, and a communication from the cylinder to the rod is made, a powerful current is produced. In the figure, the extremity of z represents the positive pole, and that of x the negative one. In this arrangement there is no evolution of hydrogen, and no local action upon the zinc or consequent unnecessary erosion of its surface. The interior of the copper cylinder becomes covered with a compact deposit of metallic copper, from the decomposition of the oxide by the nascent hydrogen.

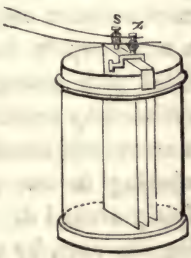
The *intensity* or power of producing electro-chemical decompositions of this battery, may be much increased by associating it with a number of others. Ten pairs, so arranged that the inactive metal of one is attached, by copper wires or strips, to the active metal or the zinc of the next, make a most powerful compound circuit, quite sufficient for nearly all the purposes of the chemist.

Daniell's battery may be constructed very simply and cheaply,

by immersing in a tumbler or jar containing a solution of sulphate of copper, a copper plate of the proper size, bent into the form of a cylinder, and having suspended in its centre upon a piece of wood supported on the top of the outer vessel, an amalgamated zinc bar. This is surrounded by a piece of bladder or of the intestine of an animal, tied at its lower part, and containing the acid liquor. Bags of very firm sail cloth, well sewn, make excellent diaphragms, and resist the action of the acid for a long time. Cylinders made by cementing coarse strong brown paper, at the edges and bottom, also answer perfectly well. The terminal wires may be soldered upon the top of the metals with which they are to be connected, and the solution of sulphate of copper may be kept saturated by the means before spoken of. Very little chemical action upon the surfaces of these batteries goes on when the voltaic circuit is not completed; nevertheless it is proper always to pour out the contents of the diaphragm or to disconnect the zinc bar after each use of them. The liquid may be kept in a separate vessel, and employed in future experiments. The solution in the outer cylinder may be allowed to remain.

Smee's Battery.—This simple and powerful apparatus is chiefly used to excite the precipitations of metals in the *electrotype* or galvano-plastic processes. As commonly constructed and shown in Fig. 467, it consists of two plates of amalgamated zinc, clamped to a piece of wood by means of a bent strip of brass, and furnished with a binding-screw. Between the plates of zinc is fixed one of platinized silver, connected at its upper end with another similar screw. The silver is covered over with a thin layer of platinum, by first roughening the surface with strong nitric acid, and, after washing, placing it in a vessel of water acidulated with sulphuric acid, to which a little chloride of platinum has been added. A porous vessel of pipe-clay or earthenware, or an animal membrane, with a plate of zinc in its interior, and containing dilute sulphuric acid, is then immersed in the other receptacle, and the silver and zinc are connected together by a wire. The platinum precipitates upon

Fig. 467.



the silver surface as a dark and granular but closely attached deposit.

This rough surface of the silver plate, presenting myriads of minute conducting points, greatly facilitates the evolution of hydrogen. The only liquid used to excite this battery consists of one part of sulphuric acid, and seven of water. The addition of a few drops of nitric acid makes it act with greater intensity, but it is not advisable to use it unless the silver is thoroughly covered with platinum.

Another form of this battery consists of a glass vessel like a tumbler, on which rests the frame which supports the metallic plates. As in the other, two screw-caps on the top of the frame allow the attachment of wires for the conveyance of the current. One of these is connected with a central slip of platinum foil, on each side of which descend amalgamated zinc plates, connected above with the other screw. Like Daniell's batteries, a series of these may be connected together, by making communication between the alternate zinc and platinum plates.

Groves's Battery.—This is the most energetic battery known. Its activity is very great, and though this prevents it from being so well adapted for galvanoplastic operations, it is the one generally employed for the development of magnetism, and is in common use in the magnetic telegraph.

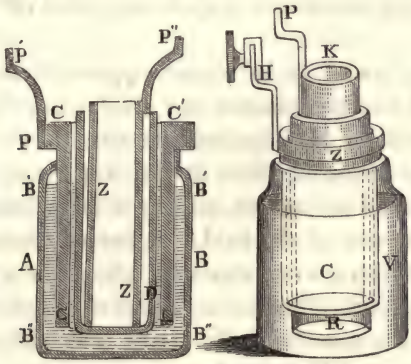
Various forms of this arrangement are met with, but in the most common one, a strip of platinum foil, furnished above with a screw-cap, is immersed in a cylinder of porous earthenware, filled with strong and pure nitric acid. The cylinder is surrounded by another one of amalgamated zinc, also provided with a screw-cap, standing on short legs, and divided by a longitudinal opening in one side, in order to permit the acid to circulate freely around it. It is placed in a glass jar or tumbler, containing one part, by measure, of sulphuric acid, and eight of water. When the circuit is completed by bringing together the wires placed in the screws, the hydrogen from the decomposed water in the outer vessel is not given off in the gaseous state, but passing through the diaphragm, combines with some of the oxygen of the nitric acid, reducing it to nitric oxide. Some of this dissolves in the acid, and the rest escapes in the form of dense red

fumes of nitrous acid, formed by its combination with the oxygen of the air.

This battery owes its intensity and rapidity of action to the absorption of the hydrogen, the good conducting nature of the materials, and the consequent concentration of the fluid. It has been said to be, when properly prepared, about seventeen times more powerful than that of Daniell. The great objection to its use arises from the escape of the irritating and poisonous nitrous acid, which is sometimes so considerable as to fill the apartment with the fumes.

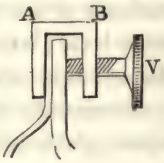
Bunsen's Battery.—This is the same in principle as Groves's battery, but is more economical, as a cylinder of porous coal is used in place of platinum. It is represented in Fig. 468. A B

Fig. 468.



is a glass vessel filled up to B′ B′ with commercial nitric acid. C and C′ are hollow charcoal cylinders, dipping into the acid as far as B″ B″, and resting on the edge of the glass by a flange. A ring of zinc or copper P encircles the top of the charcoal cylinder, and terminates in an appendage P′, for connecting it with the wire. D D, which are diaphragms of porous earthenware, contain an amalgamated hollow zinc cylinder Z Z, with its appendage P″, also intended for communication, and which is immersed in dilute sulphuric acid. The connections are made by means of the clamp A B, Fig. 469, and screw V, which are shown in place at H, Fig. 468. The perfect contact of these appen-

Fig. 469.



dages, screws, and the ribbons or wires of copper connected with them, must be secured, by keeping them clean and bright by rubbing with sand paper. When the battery is about to be used, the glass vessel is half filled with equal parts of commercial nitric acid and water, and the diaphragm with water acidulated with sulphuric acid. The coal cylinder is prepared by pressing a thorough mixture of one part of caking coal and two of coke with a little rye flour, into a cylindrical mould of sheet-iron, in the centre of which is a core of wood or pasteboard. The mould, after being closed by a movable cover well luted on, is heated gradually to redness, and the calcination is continued until the disengagement of gas ceases. The cylinder is then taken out, soaked in a strong solution of molasses, dried, and again calcined by an intense heat, in order to increase its firmness of texture. After this, its surface may be smoothed off with a file, or in a lathe.

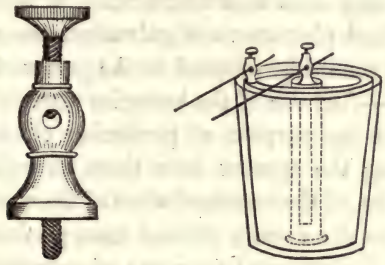
This battery is said to be almost equal to Groves's in power. Professor Bird has constructed one similar to it by the use of a black lead crucible. He ignited the crucible for a short time, and, when thus prepared, filled it with nitric acid, and wound a wire tightly around its outside, making it serve both as a support and as the conductor of the fluid. A bar of amalgamated zinc, also connected with a wire, was then placed in a porous cylinder containing dilute sulphuric acid, and the whole was immersed in the acid of the crucible. He states that, although powerful, it is much inferior to Groves's battery.

In the use of any of the above-described batteries, care must be taken not to fill either of the receptacles too full of the liquid, since on immersing the metals or charcoal, some part of it might overflow and mix with that of the other vessel, to the injury of the surfaces. After the insertion of the cylinders or bars, the surfaces of the two liquids must be as nearly as possible upon the same level; any deficiency in this respect must be regulated by the addition of more fluid.

Connection of Batteries.—The connection between the different plates of batteries is very conveniently made by means of the binding-screw, Fig. 470. The wire by which the communication is established is passed through the hole in the side, and kept in its place by the movable screw in the top. The screw

below serves to fasten the arrangement firmly into a hole of the proper size, in the top of either plate. The operator should be supplied with a number of these, as they permit him to unite and

Fig. 470.



disconnect the different parts of an apparatus with the greatest ease and rapidity. They are shown in the figure, attached to the copper and zinc plates of a simple circuit, with the wires, of which the ends form the poles, passing through them.

Wire for Battery Purposes.—Copper wire is more often employed for connecting the different parts of a voltaic circuit than any other, on account of its high conducting power, its flexibility, and its not being susceptible of magnetization by the passage through or around it of a galvanic current. Its thickness should be proportioned to the energy of the battery, and it should be as short as possible, because a great length of wire causes resistance to, and loss of the fluid proceeding from a battery of moderate power. Its connecting parts, as well as those of the plates or screws to which it is attached, must be bright and clean. In order to insure perfect contact, it is advisable to amalgamate the extremities of the wire; which is done by washing them with a solution of nitrate of mercury, and dipping them afterwards in metallic mercury.

When it is desired to break and renew the connections often or very rapidly, the common mode of attaching the wires is found to be inconvenient. In that case, a little cup made of copper, or other metal which does not too readily amalgamate with mercury, is partly filled with that metal, and the wires are received in the cup, a depression in the bottom of the latter being often made so as to hold them more firmly in their place. By keeping one of the wires immersed in this cup, the connection may be made

complete or broken at will, and without disarranging any part of the apparatus, by simply placing the extremity of the other wire in its appropriate cup, or taking it out.

The wires are, in one point of view, the most interesting parts of the battery, as it is at their extremities, or the *electrodes*, that the most important phenomena of galvanism are exhibited. Their size and length should be adapted to the power of the battery.

Electrolysis.—Any one of the batteries already mentioned may be employed for the purpose of producing chemical decompositions, by passing the current from them through the substance, from pole to pole, of the terminal wires of the series. As electro-chemical changes are usually effected most perfectly by a current of *intensity*, as distinguished from one of *quantity*, which is more active in producing light, heat, and electro-magnetism, a number of pairs of plates or cylinders, varying with the difficulty of the decomposition, are employed. The other results spoken of are generally obtained by using a small number of plates with large surfaces. A combination of small batteries, made upon the plan of Daniell's, is, perhaps, the most active of all in producing chemical change.

Whatever form of apparatus is used for such decompositions, particular attention must be paid to the proper connection of the alternate metals, and to the close contact of the wires, as well as the other circumstances before spoken of in reference to their relative size. The points of the wires should, in most cases, be made of platinum, as that metal is the best conductor of the fluid, and is not liable to be chemically acted on by any of the substances evolved from the electrolyte.

Any one of the class of bodies called *electrolytes*, which includes all those known to be capable of decomposition by electricity, may be exposed to the voltaic influence by being placed between the *electrodes* or extremities of the wires, so as to be the medium of communication between them. This is effected in various ways, as the substances differ in being solid or fluid, and good or bad conductors of the influence.

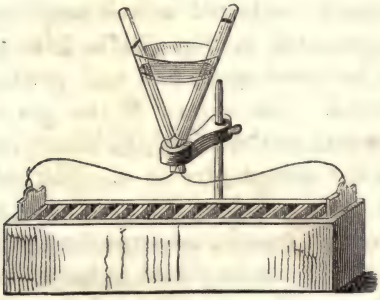
Many solutions, like that of iodide of potassium, admit very readily of decomposition. A solution of this salt may be easily decomposed by a battery consisting only of a wire of zinc and one of copper. Water alone, however, may require the power of

a number of cells of Daniell's battery to separate it into its elements. The addition of a little common salt, or of almost any saline body, will make the electrolysis of it much more easy by increasing its conducting power.

In the decomposition of water, and, indeed, in most cases in which gaseous components of bodies are eliminated from liquids, platinum strips are attached to the ends of the wires, thus making the surfaces of contact much greater. These strips, which may be made of platinum foil, are placed parallel and as close to each other as is possible, without their being actually in contact. Their touching each other would effectually prevent all chemical action, as the voltaic fluid would be directly transmitted through the wires from the positive to the negative plates.

When the electrodes are placed in a vessel of water, and the battery is made to act properly, bubbles of hydrogen will ascend from the end of the wire or foil connected with the negative end, and oxygen from that of the positive one. These gases can be collected in a tube closed at one end, or a jar previously filled with water, and inverted over the wires; or they may be separately received in different vessels. As water consists of two volumes of hydrogen and one of oxygen, of course the quantity of the first given off, will be twice that of the last. Fig. 471 re-

Fig. 471.



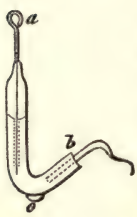
presents a mode of effecting this decomposition in which the terminal wires of a trough arrangement are passed through a perforated cork into water contained in a funnel. The end of each wire is placed directly under a test-tube previously filled with water, and inverted in the funnel. The ascending gases

displace the water, occupy the tube, and may, if necessary, be accurately measured.

As the quantity of electricity set in motion by the battery is in direct proportion to the amount of zinc dissolved in it, so are the effects of chemical decomposition always proportionate to the former; this being thus always in a certain relation with the equivalents both of the products of electrolysis and of the portion of zinc acted upon. Thus, one grain of hydrogen, given off at the negative pole, indicates that thirty-three grains of zinc have been dissolved during the time of the action. Upon this principle Faraday constructed his *voltameter*, which affords the only means known of accurately measuring the galvanic influence. That form of this which is most employed, is one in which strips of platinum foil, attached to the wires of a battery, are placed opposite and near to each other in a jar or bottle, from which a tube issuing, enters under a graduated jar inverted over the pneumatic trough, all of these vessels being full of water. By the measure of the gases collected, the quantity of electric force can be estimated. By placing strips of platinum upon the ends of the wires in Fig. 471, and substituting a single graduated tube with a wide or funnel-shaped mouth, for the two which are seen in the cut, the same result may be attained.

Faraday describes a convenient form of tube for the collection and examination of gases evolved from either electrode, in experiments conducted upon a small scale. This tube, represented in Fig. 472, is filled with the solution to be acted upon, and held in the position represented. The nature of the gas to be collected, depends on the end of the battery, which is fastened to the curved wire at *a*. The other electrode is to be loosely inserted at *b*, so as to allow the gas given off from it, to escape through the open orifice. It should not be placed so far within the extremity of the tube as to permit any bubbles of the gas to pass around the bend, and to mix with that in the upright limb. The wire *b* is to be removed when a sufficient amount of gas has been collected, and the latter can then be transferred to a suitable vessel and examined.

Fig. 472.



The methods of subjecting substances to the action of the bat-

tery are very numerous. When the electrolyte is a fluid, it may be placed in any one of a great variety of suitable receptacles. In all cases it must be recollected that the electrodes should be brought as near together as possible, so that the small amount of the substance which is directly between them, shall have the full effect of the current concentrated upon it. Decompositions of a drop of fluid may be made by placing it upon a glass plate, and bringing the poles in contact with its sides. Larger quantities may be received in a watch-glass or other concave piece of glass, or in a cup of the proper size. A very convenient mode of subjecting liquids to the current, so that the results of the decomposition can be easily inspected by the observer, is that of closing one end of a piece of glass tube tightly with a cork, and supporting it in an upright position by passing one of the wires of the battery perpendicularly through the cork. The tube may then be filled with the liquid, and the other wire, bent downwards, may be immersed in it, and placed alongside of its fellow. In nearly all such decompositions, the ends of the poles should be armed with strips of platinum foil, on account of the greater surfaces of contact presented by them.

When it is desired to direct the electrolytic influence upon a large surface of a liquid, a piece of platinum foil attached to one pole may be hollowed out into a cup-like form, and the substance may be placed in it; or the terminal wire may be made to support and communicate with a platinum crucible, by being wound around it. The other wire can then be immersed in the liquid, and prevented from touching the vessel by the intervention of a piece of glass tube.

Production of Heat and Light by Galvanism.—The physical effects of galvanism, among which are the production of heat and light, result generally from the passage of a current of great quantity and of feeble intensity, through an insufficient and imperfect conductor, the resistance of the latter impeding the current, and increasing its calorific power. The batteries employed for fusion and deflagration generally consist of a very small number of pairs with extensive surfaces, which will develop a great quantity of electricity. Usually these are the best batteries for physical experiments, but occasionally those consisting of a large number of plates are found useful for such purposes. A

single pair of very moderate size will effect these results in a small way. Thus, Dr. Wollaston fused a very fine wire of platinum by means of a small battery, made of a lady's thimble and a rod of zinc. We have before stated that the intensity or decomposing power of the galvanic fluid is increased by placing batteries in connection so as to multiply the number of plates. Batteries may also be associated together so as to increase their calorific and light-producing power. Any number of troughs like Wollaston's may, for this purpose, be placed,—not as before, end to end,—but sidewise, and the cells at either end of each may be connected with the same cells of the others by two wires going across the series, and so bent as to be in perfect contact with the last plates. The projecting ends of these wires on one side are to be used as the poles of the battery.

Daniell's, or any other of the cell batteries, can be made capable of producing the physical phenomena of electricity, by paying attention to the size and conducting power of the wires or other bodies to be heated; but the quantity of the fluid is much increased by connecting a number of them so as to make them equivalent to a single pair. This can be done by connecting together all the copper or platinum plates by means of wires, either soldered to them or inserted into the binding-screws already spoken of. The zinc bars or cylinders are to be brought into contact in like manner, and the poles may be made by attaching wires to any two of the opposite pieces of metal.

The wires of such batteries should all be made of larger size than those which are employed in the ordinary arrangements.

When the electricity developed in a powerful battery is passed through conical pieces of charcoal placed upon its poles, and these are brought into contact, and then withdrawn to a short distance from each other, the interval becomes occupied with a brilliant spark or arch of flame, the light of which is often too vivid to be borne by the eyes. The heat given out is also very intense, and gases and other bodies are sometimes subjected to its influence for the purpose of being decomposed. Carburetted and sulphuretted hydrogen are both thus affected by it. The wires may be twisted around two pieces of fine, well-burnt charcoal, which are then brought together. The brilliancy of the spark or arch passing between the points of charcoal, serves often

to indicate the power and good condition of the battery. When a very powerful current is set in motion, it is advisable not to make the contact by means of the hands, but to use insulated dischargers analogous to those employed in electrical experiments. The wires may be brought together and disconnected by means of clamps or small vices attached to wooden handles. These may be screwed on and taken off at pleasure. The charcoal used in these experiments must be of the best quality. It is properly prepared by packing pieces of box or other suitable wood, two inches long, and a quarter of an inch thick, in an earthenware crucible, and after covering them up with dry sand, heating them until they cease to flame. The best pieces must be selected and preserved for use in a well-stoppered vessel.

Various substances ignite and burn with brilliancy between the galvanic poles. Metallic leaves or foil of different kinds may be conveniently burned by taking them up upon the point of one electrode, and bringing them in contact with a plate of polished tinned iron, which is attached to the other. In this way the different appearances and colors of their flames are shown.

A platinum wire stretched between the poles of a battery, will attain a red or white heat, and, if offering sufficient resistance to the passage of the fluid, may even be fused. It must not be too thin, as the electricity may be sometimes so much retarded as to produce no visible indications of heat. A wire of the proper size will often remain at a red heat for a great length of time if a constant battery is used.

The power possessed by the battery of igniting platinum wire, enables us to apply heat in situations in which it would be difficult or impossible to do it by other means. By its use, substances placed under water may be ignited or exploded, if necessary, at a great distance from the operator. Out of the laboratory, it may be employed for the purpose of exploding gunpowder in mines, or under ships, and in other positions far removed from the source of electricity: while, in it, it may be used for the explosive decomposition of various gases.

Dr. Hare has taken advantage of this power in the construction of his sliding-rod, aqueous, eudiometer. This instrument consists of a glass vessel, with a capillary orifice closed by a spring and lever in its top, and connected below with a socket,

and a tube in which a graduated piston moves. A fine wire of platinum is stretched across the middle of the vessel, between two brass wires, which pass through the socket below, and terminate in legs, which are made capable of connection with the cups upon the poles of a battery. The instrument having been filled with water, the gaseous mixture is drawn into it in the proper quantities by pulling out the piston to regulated distances, and is then exploded by the ignition of the wire, after the capillary orifice has been closed. This last is now again opened, but under water, enough of which enters to supply the vacuum produced by the condensation. The amount of undecomposed air which remains, is indicated by the distance through which the rod has to be passed for the purpose of expelling it all from the glass vessel.

Dr. Hare uses for the ignition of the wire in this experiment, his calorimotor of two pairs of plates. He has constructed a variety of arrangements for procuring the heating effects of the battery. In one of these, twenty sheets of copper, and the same number of zinc plates, united separately to two bars of metal, were secured in a wooden frame, so as to leave a space between them of a quarter of an inch. A rope, passing over a pulley, was attached at one end to the frame, and at the other to a counterpoising weight. The frame could be lowered by means of the rope into a cubical box containing the acid liquor. Another form of Hare's battery is so constructed that the vessel containing the acid is raised up to and lowered from the plates, when necessary, by means of a lever connected with pulleys. By this most convenient and powerful battery, constructed with a new arrangement of the plates, the most intense galvano-ignition and deflagration may be accomplished.

This apparatus, the description of which might, perhaps, have been more properly introduced along with the account of other batteries, is shown in Figs. 473 and 474. We extract the description of it from Hare's Compendium.

"The two forms of calorimotor, represented in Figs. 473 and 474, have been much used by me for what is described in my Compendium as '*galvano-ignition.*' (C, 335.) Within any cavity, ignition of any intensity short of fusing platinum may be produced, by making a platinum wire the subject of a galvanic discharge from an instrument of this kind. I first resorted to this

process in the year 1820, for the purpose of igniting gaseous mixtures in eudiometers of various forms. In June, 1831, I applied it to ignite gunpowder in rock blasting; and to this object it was subsequently applied, agreeably to my recommendation, by Colonel Pasley, Professor O'Shognessy, and others.

Fig. 473.

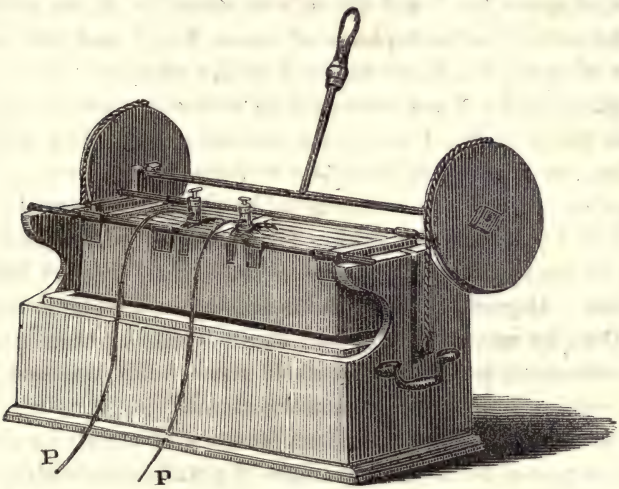
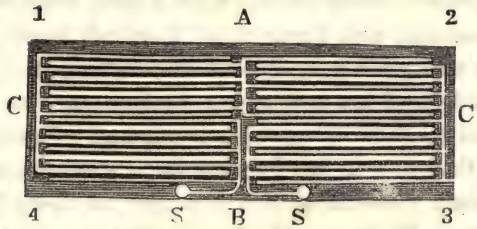


Fig. 474.



"This machine consists of sixteen plates of zinc, and twenty plates of copper, each twelve inches by seven, arranged in four galvanic pairs. The plates are supported within a box with a central partition of wood A B, dividing it into two compartments. Each of these may be considered as separated into two subdivisions, by four plates of copper between the letters C C. Of course the box may be considered as comprising four distinct spaces, No. 1, No. 2, No. 3, and No. 4. The circuit is established in the following manner. Between the zinc plates of compartment No.

1, and the copper plates of compartment No. 2, a metallic communication is produced by soldering their neighboring corners to a common mass of solder, with which a groove in the wooden partition between them is filled. With similar masses of solder, two grooves severally made in the upper edges of each end of the box are supplied. To one of them, the corners of all the copper plates of space No. 1 and the zinc of space No. 4, are soldered. To the other, the zinc plates of space No. 2 and the copper plates of space No. 3, are soldered in like manner. Lastly, the zinc plates of No. 3 are connected by solder in a groove, and the copper plates of No. 4 are in like manner connected by solder in another groove. Upon the ends S S of the solder just mentioned, the gallows-screws are severally soldered, and to these the rods P P, called poles, are fastened. The means by which the acid is made to act upon the plates must be sufficiently evident from inspection. Depressing the handle causes the wheels to revolve, and thus, by means of the cord which works in their grooved circumferences, to lift the receptacle which holds the acid, until this occupies interstices between the plates."

ELECTRO-METALLURGY.—The deposition of metals by electric action is one of the modern triumphs of practical chemistry. The art dawned in 1805 with the discoveries of Brugnatelli; but no substantial benefits were derived from it until 1838, when Jacobi, of St. Petersburg, and Spencer, of England, applied the principle to the utilitarian purposes of life. The subsequent invention, by Daniell, of his well-known battery gave an impulse to the art which resulted in many gratifying and wonderful improvements; so that now it has become, in its greatly advanced condition, a prime element of the economy of many branches of manufacture. Plating, gilding, stereotyping, medal copying, engraving, and kindred arts, are all largely indebted to electro-metallurgy for many of the facilities which at present promote and distinguish their progress.

Those who may wish to experiment in this interesting branch of scientific art will find ample instruction in the following pages.

Any of the many forms of batteries previously described may be used for electrotyping, but the best is Smee's. Care should be taken to observe the directions heretofore given for the treat-

ment and management of batteries; their good condition, proper arrangement and management, being necessary to success.

The intensity and quantity of the galvanic current should be proportional to the work to be done.

Preparation of Articles to be Plated or Copied.—In gilding and silvering, it is merely necessary to have the objects perfectly clean and bright. This is effected by first boiling the articles in a solution of caustic soda or potassa, and afterwards immersing them in dilute nitric acid, and rinsing with water. They are further cleaned by rubbing with a hard brush, and sometimes a little fine sand or tripoli.

Moulds.—Many substances are used for making moulds; among the best are beeswax, plaster of Paris, fusible metal, and gutta percha.

Wax moulds are prepared by melting the wax over a water-bath, and stirring in one ounce of white lead to each pound of wax. The wax should be clear and free from impurities.

If the object to be copied is a medal, it should be brushed over with sweet oil, and the excess of oil removed with a cloth. A slip of metal or card is bound round the edges of the medal, so as to form a rim. The wax being melted, the medal, to prevent air-bubbles, is held in an inclined position, and the wax, which should not be too hot, poured gently on the lowest part, and allowed gradually to spread over the surface of the medal by bringing it to a level when it is filled to the top of the rim with wax. As soon as the wax begins to set, the band should be removed to prevent cracking. Let the medal and wax remain together until entirely cold, so that they may be easily separated.

If it is desired to take a wax mould from a plaster-cast or medallion, a similar course is followed, the medallion being first prepared as follows: the medallion is warmed a little, brushed over with boiled linseed oil, and allowed to dry perfectly. It then presents a polished appearance and is ready for the wax.

Instead of oil, water is often used; the plaster being saturated with it by placing the back of the medallion in the water, care being taken not to allow the water to flow over the face of the medallion.

Plaster of Paris moulds are made by mixing the finest calcined plaster with water, to form a thin paste about the consistence of

cream. A little of this paste is poured upon the object and well brushed into every part with a camel's hair brush, and then more of the paste is added to produce the requisite thickness. It is allowed to set and dry; the drying can be facilitated by heating in an oven or otherwise.

The fusible metal of which moulds are frequently made is an alloy of five parts of lead, three of tin, and eight of bismuth, and melts below 212° F.

Care and practice are requisite for producing a good and sharp casting; and the metal must not be poured too hot. Commence by pouring sufficient of the melted alloy into a suitable vessel,—taking the precaution to skim the *dross* from the surface of it with a card,—and when it is nearly congealed, bring the matrix down upon it quickly and with considerable force, and let it remain until the mass has perfectly cooled. When done with skill, a reverse will be obtained with all the sharpness and perfection of the original.

Gutta percha is probably the substance best adapted for taking moulds for electrotyping. It is applicable to metal, wood, glass, stone, &c. It needs only to be softened by heat either in warm water or by a steam-bath, spread into suitable form, laid and pressed upon the object to be copied, and allowed to cool under the pressure, when the mould will be fit for use.

Sulphur is sometimes used for moulds; and very beautiful impressions can be made also with sealing-wax, which takes the minutest lines of the original. Reverses may be procured in lead by forcing the matrix into a bright surface of it, either by pressure or blows.

Non-conducting Substances.—As gutta percha, wax, plaster of Paris, and many of the materials used for making moulds are non-conductors, it is necessary to coat the surface on which it is desired to deposit metal with some conducting substance. The best and easiest of application is plumbago or black lead. A copper band or wire is fastened around the edge of the mould, and the ends formed into a hook, or punched with holes, to make the connection with the battery. A fine brush is dipped into the plumbago and passed thoroughly over the face of the mould, all excess of black lead being carefully removed, and the brushing continued until every part is covered and brightly polished. This

treatment will insure a quick and even deposit. In wax moulds it is only necessary to insert, in the edge of the mould, a piece of copper by which to attach it to the battery-pole. In every case, however, the conducting coating must extend to and be in contact with the battery connection. In using metal moulds, those parts on which metal is not to be deposited should be covered with wax or some kind of varnish.

The battery connection is most conveniently and perfectly formed by soldering a copper wire, flattened, at one end to the metal mould.

Bronze powder is sometimes used instead of plumbago and in the same manner. Flowers, and other objects to which plumbago is not applicable, may be rendered conducting by a film of gold or silver. This is applied through the medium of a solution of phosphorus in bi-sulphuret of carbon. The solution is made by dissolving 1 ounce of phosphorus in 15 ounces of bi-sulphuret of carbon, and adding thereto 1 ounce of wax, 1 ounce of asphalte, 1 ounce of spirits of turpentine, and 1 drachm of india-rubber. The india-rubber must be dissolved in turpentine, and the asphalte in the phosphorus solution. The wax is melted first, the turpentine and india-rubber stirred in, and then the asphalte and phosphorus solution added.

This should be done with caution over a water-bath, as the components are highly inflammable. The bi-sulphuret of carbon being very volatile, the solution should be kept in a well-stoppered bottle. "The solution, as above prepared, is applied to the surfaces of non-metallic substances by immersion or brushing; the article is then dipped in a dilute solution of nitrate of silver or chloride of gold; in a few minutes the surface is covered with a fine film of metal, sufficient to insure a deposit of any required thickness on the article's being connected with a battery. The solution intended to be used is prepared by dissolving 1 ounce of silver in nitric acid, and afterwards diluting with 3 gallons of water; the gold solution is made by dissolving 2 pennyweights of gold in aqua regia, and then diluting with a gallon of water."

Gold Solution.—Convert a half ounce of gold into terchloride, dissolve the gold salt in a little water, and add it to a solution of four ounces of cyanide of potassium in two quarts of water and filter.

Silver Solution.—Take of cyanide of silver 1 ounce, cyanide of potassium 10 ounces, water 6 pints; dissolve the cyanide of potassium in the water, add the cyanide of silver, and filter the solution.

Probably a better way to make the solutions of gold and silver in cyanide of potassium is with the battery. Immerse, in a solution of 1 part cyanide of potassium to 16 parts of water, a silver plate, connected with the positive pole of a battery, complete the connection with the negative pole, and keep up the action of the battery until silver is freely deposited on the negative pole. The same process is followed for gold, care being taken to substitute a gold for the silver plate.

Sulphate of Copper is the best salt for the reduction of copper. A nearly saturated solution, acidulated with a few drops of sulphuric acid, is used. One pound of the sulphate in six pounds of water is a good strength.

Cyanide of Copper is sometimes used for depositing copper or iron. It is made by dissolving the oxide in an excess of cyanide potassium, or by making a sheet of copper the positive pole in a solution of cyanide of potassium.

Platinum, zinc, and most of the metals can be reduced from their salts by the battery; but for electrotyping they are seldom or never used.

To have the metals adhere well in gilding and silvering, the articles to be plated must be well cleansed. As silver is generally precipitated on copper, the article is boiled in caustic potash or soda well rinsed with water, dipped in dilute nitric acid, afterwards immersed in a weak solution of nitrate of mercury, and immediately placed in the silvering solution. Gold is usually deposited on silver. The silver object is treated as before with caustic lye, rinsed, and, when dry, is thoroughly scratched with a scratch-brush, which is a bunch of fine wires made into a brush. It is then ready for the battery. In gilding, the solution should be maintained at about 150° F. by a water-bath.

To avoid opposite currents of electricity in the depositing solution from an exhaustion of the solution around the negative pole, and a dense solution forming around the positive pole, the articles should be kept in motion during the deposition; for this motion also prevents that crystalline deposit deemed so objectionable.

To prevent the adhesion of the matrix to the deposited metal, Mr. Mathiot, of the United States Coast Survey, recommends that the engraved copper plates, &c., be coated in a battery with a thin film of silver, and afterwards washed with a dilute solution of iodine in alcohol,—about one grain of the former in a quart of the latter.

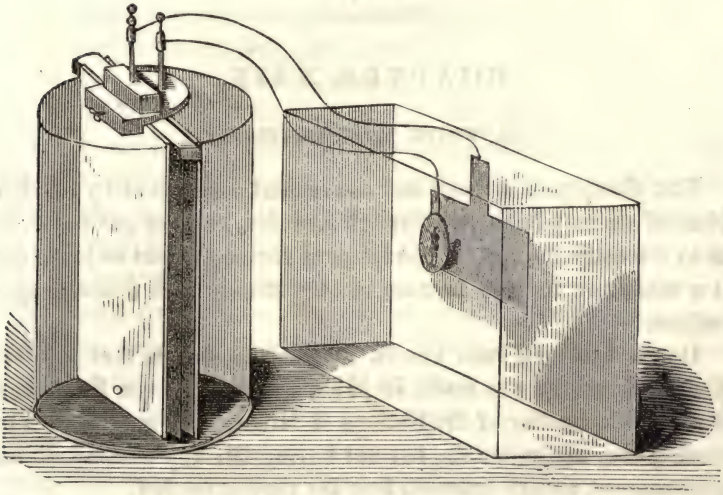
Dusting with black lead, or spreading a little oil over the surface of the article, care being taken not to use an excess, will cause the metals to separate easily. A little wax dissolved in spirits of turpentine also answers well.

Solutions should be kept covered from the air and dust; and the working of the batteries is promoted by having the surrounding atmosphere of a warm temperature.

A few drops of bi-sulphuret of carbon added to a silver solution will produce a bright deposit.

In inserting the articles in the solutions the air adhering to their surfaces, and which prevents a contact of the metals, may be dispelled by moving the articles about in the liquid or by heating the solution.

Fig. 475.



The plates attached to the positive poles should be parallel to the articles on which the metal is to be deposited and present the same amount of surface.

A battery, if in proper working order, will, when the connec-

tions are made, show a disengagement of gas at its negative metal; but no gas should be seen to escape at either pole.

Bronzing.—To give the copies of medals and other objects an antique or bronzed appearance like the original, several means are employed. A dark bronze is produced by dipping the object in very dilute nitric acid,—say half an ounce of acid to a pint of water,—and, after drying, heating it gradually and uniformly. The color is deepened in proportion to the heat applied. Sulphuretted hydrogen or hydrosulphuret of ammonia may also be used. Afterwards polish with a brush. Green bronzes are formed by immersing the articles in a solution of chloride of ammonium or chloride of sodium, or by exposing them to the fumes of chloride of lime. The depth of the bronze is regulated by the length of time during which the articles are subjected to the galvanic action. A coating of black lead and subsequent heating of the article, gives a beautiful bronze. A thin film of oil or wax, and heating until the grease commences to decompose, produces a good bronze. Immersion in a solution of chloride of platinum also gives a handsome bronze.

CHAPTER XXIX.

BLOWPIPE MANIPULATIONS.

THE blowpipe is a small and convenient instrument by which a blast of air may be forced through a candle, or oil or gas flame, so as to intensify the heat of the latter to such an extent as to render it a substitute for the furnace in very minute and delicate operations.

Its use had long been known in the arts, but its first application to chemistry was made, in 1738, by Anthony von Schwab, a Swedish Counsellor of the College of Mines. He employed it in testing ores and minerals, but not having left any account of his experiments, we are ignorant how far they extended.

In the hands of Cronstedt, a Swedish Master of Mines, it became a ready means of distinguishing and arranging minerals according to their characteristic behavior with fusible reagents.

Von Engeström published, in 1770, an English translation of

Cronstedt's system of mineralogy, with an account of the methods employed by him in testing minerals; but yet the instrument found no general favor, and for a long time afterwards had no more extended application than to the testing of the fusibility of substances, and their solubility in borax-glass.

Bergmann enlarged the sphere of usefulness of the blowpipe, and employed it in analytical investigations, to detect the presence of minute quantities of certain mineral substances. His work on the use of the blowpipe appeared in 1779. Bergmann's feeble health caused him to seek the assistance of Gahn in his experiments, who became, under his instruction, so expert in the use of the blowpipe that he was able to detect with it substances which had escaped the most careful analysis in the moist way. But Gahn could never be prevailed to give to the world the results of his experience. Fortunately for science, his pupil, Berzelius, recognized the value of this instrument, and after testing with it the reactions of most of the minerals and mineral substances then known, published his valuable work on "The use of the Blowpipe in Chemistry and Mineralogy."

After the publication of this work, in 1821, the use of the blowpipe become general among chemists and mineralogists. Harkort first attempted to make quantitative assays with its assistance; but it is to Plattner, Professor of Metallurgy in the Saxon Royal School of Mines, that the method of performing quantitative determinations by the blowpipe owes its great exactness and simplicity. His admirable work "On the Art of Assaying with the Blowpipe," furnishes the most accurate and complete information on this branch of science, and will be a lasting monument to his patient industry and genius.

A simple form of the blowpipe, and that originally adopted for soldering, &c., by metal-workers, is represented in Fig. 476. It consists of a tapering tube of brass, curved nearly at a right angle, a short distance from the smaller end. The bore terminates in a very small perforation. A steady stream of air is forced through it by the action of the muscles of the cheeks, and directed against the flame of a candle or lamp. This form of the blowpipe has the disadvantage of promoting, by long-continued blowing, the condensation of the moisture of the

Fig. 476.

breath in the tube. This obstructs the passage of air, or, being driven out into the flame, very seriously interferes with the success of the operation. It, therefore, becomes necessary to construct the blowpipe with a chamber in which the condensed moisture may lodge.

The instrument which best fulfils all the requirements for general use is that devised by Gahn, and recommended by Berzelius.

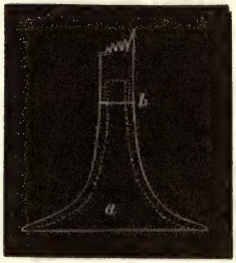
It consists of a slightly tapering tube (Fig. 477), fitting into a

Fig. 477.

cylindrical chamber, an inch long, and half an inch in diameter. Into the side of this chamber, a much shorter and smaller tube is inserted at a right angle. The end of this tube is covered with a tip of platinum, Fig. 478, with a fine aperture. Plattner recommends two such tips, with perforations of different dimensions. The finest, which is used in qualitative tests, has an aperture 0·4 millimetre in diameter. The other, for such tests as require a stronger heat, has a slightly larger aperture. Tips of platinum are preferable to those made of any other metal, on account of the facility with which they may be freed from soot by heating them on charcoal. If tips of brass or silver are employed, the aperture may be cleaned with a fine splinter of horn. The length of the blowpipe must be adjusted to the sight of the operator, so that the test object may be held at such a distance as to be distinctly visible. The blowpipe should be provided with a mouth-piece of ivory or horn *a b*, Fig. 479. The form of the mouth-piece recommended by Plattner is trumpet-shaped, and it is to be pressed against the lips instead of being held between them. The outer edge must have a sufficient spread to present a flat

Fig. 478.

Fig. 479.

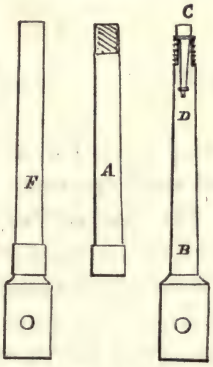


surface to the lips, so that any undue pressure may be avoided. The diameter of this mouth-piece should not exceed one and one-fourth to one and one-half inches.

The use of this mouth-piece very much diminishes the fatigue of the muscles of the lip in long-continued blowing, and the difficulty at first felt in preventing the escape of air at the corners of the mouth is easily overcome by practice. The drawing exhibits it in full size.

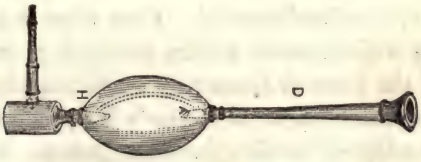
Mitscherlich has so modified the form of Gahn's blowpipe as to render it very portable. The moisture-chamber is diminished in length, and permanently attached to the long tube, as shown in the drawing, Fig. 480. This tube is made to unscrew in the middle, so that the small tube C, with its platinum jet D, can be slid into the part connected with the chamber, and the other half A passed over it as a cover. The whole forms a short, smooth cylinder, which may conveniently be carried in the pocket. The mouth-piece should be silvered; or a separate mouth-piece of ivory may be made to screw into it.

Fig. 480.



For the purpose of relieving the cheek muscles at intervals, without interruption to the blast, the blowpipe may be constructed according to De Luca's suggestions, and as exhibited in the annexed drawing, Fig. 481. Between the mouth-piece and the

Fig. 481.



chamber for collecting the moisture, an india-rubber bulb or bag is adjusted by ivory collars upon the tubes D and H, the projecting ends of which are connected by means of a light metal rod. The escape of air, when the mouth may be removed, is prevented by a valve at A opening outwards.

The proper material for the construction of blowpipes is real or German silver. When made of the latter, it will be advisable to galvano-plate them, otherwise the base metal, by constant handling, will impart an unpleasant odor, and dirty the skin. The great conducting power of both of these materials is apt to cause the instrument to become overheated by a long-continued blowing. Brass blowpipes are very objectionable, as they oxidize readily at the jet, and moreover give a metallic taste and odor.

In emergencies, a very convenient blowpipe may be made from a common tobacco-pipe, by accurately closing the bowl with a tight cork, and fitting in the latter a glass jet. This latter is formed by drawing out a small tube to a fine point, and smoothing the end in the flame until it becomes thick, but, at the same time, presents a perfectly round and small aperture.

Fig. 482.

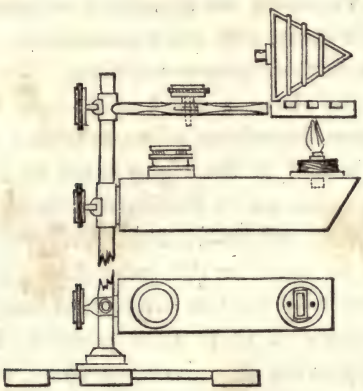
The Combustible.—Almost any flame which is strong enough to afford the requisite heat may be used with the blowpipe. In laboratories where coal-gas is burned, its use will be found very convenient. The form of burner which we have found to answer best is that known as Solliday's patent, a single slit burner, with a small cylinder fitting closely around it, and reaching a short distance above the base of the flame. This cylinder, or jacket, has two shallow incisions lying in the axis of the flame, in one of which the jet of the blowpipe may be made to rest. For very small operations the flame of a candle may be employed; but for many reactions it does not yield sufficient heat, and in quantitative assays its use is quite inadmissible. The best fuel for this purpose is olive, or refined rape oil. Care must be taken to select oil which burns without much smoke, and with a colorless flame, as the color of the flame is frequently a characteristic reaction.

Harkort's modification of Berzelius's lamp is the most convenient and best adapted for blowpipe experiments. It consists of a sheet brass, horizontal cylinder, four and a half inches long, and slightly tapering to one inch width at the end nearest the operator, as shown in Fig. 483.

It is made to slide upon an upright brass rod, and can be adjusted to any height by a screw. At one end of the lamp is an

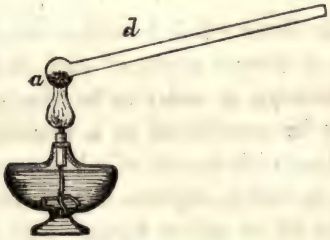
opening for introducing oil, and at the other is the wick-holder. Both of these openings are closed by screw-caps, with the thread

Fig. 483.



cut on the inside. The escape of oil is prevented by washers cemented to the caps with shell-lac and wax. The wick-holder has its greatest breadth at right angles to the axis of the lamp, and must be cut off obliquely, to allow the flame to be directed downwards. Cylindrical woven wicks, such as are made for Argand burners, are best adapted for this lamp, and they are pressed flat and folded lengthwise, so as to be introduced fourfold. Care must be taken that the wick does not fit too tightly, else its capillarity will be impaired, and the ascent of the oil obstructed.

Fig. 484.



Moreover, the wicks must be entirely free from any lime that, may have been used in the bleaching of them, as that earth,

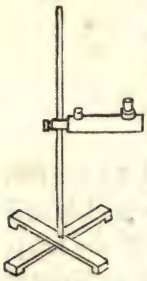
in giving a reddish-yellow flame itself, may obscure the flame reaction of the substance under process.

The rod in which the lamp slides also carries a triangle, which is very convenient for supporting small capsules, crucibles, &c., over the flame. To render the apparatus compact and portable, it is constructed in parts, with screw connections. Fig. 485 shows the several pieces in their proper positions.

In addition to the above, a small spirit-lamp is often needed for applying a flame directly to tubes, crucibles, &c., Fig. 484.

The blowpipe is held in the right hand, as shown in Plate 3, and in such a manner as to facilitate a direction of the flame upon the substance under process. This latter, as will be seen in the same drawing, is held upon a support by the left hand; care being taken to retain the arms in their fixed position, for unsteadiness will prevent an uninterrupted action of the blast in the assay.

Fig. 485.



The mouth furnishes the blast, which derives its force from the muscles of the cheek. To prevent fatigue of the respiratory organs, communication between the mouth and chest must be closed during the blowing, and breathing maintained through the nostrils. A few days' practice removes all the difficulty at first experienced in producing a continuous, steady current; and it is by this means only that proficiency can be acquired. The operation is commenced by filling the mouth with air, expanding the cheeks, and then keeping up a steady forcible pressure with the muscles, respiration being allowed to go on as usual through the nose.

The Flame.—The flame which furnishes the heat for blowpipe operations consists of several parts, of each of which it is necessary to have a knowledge in order to be able to manage it skilfully. Flame may be considered as a miniature furnace, producing an intense heat with the aid of a blowpipe. It consists of four distinct parts, as will be explained by the drawing, Fig. 486, which represents an oil or tallow flame. The base *a b* is a distinct blue conical envelope surrounding the burning wick, and which gradually diminishes as it rises, and eventually disappears when it reaches the point where the flame elongates perpendicu-

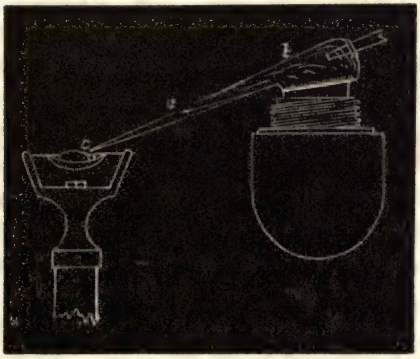
B. Barber Del.

larly. The central portion is the dark cone *c*, surrounded by the brilliant, luminous envelope *d*, which is the sphere of illumination. Exterior to this, and enveloping the whole is the faintly luminous curtain *a e b*, forming the hottest portion of the flame, and presenting its greatest intensity at the point *f*. From this point the heat gradually diminishes, both upwards and downwards.

Fig. 486.

The structure of the flame is explicable as follows. The wick being an assemblage of threads, exercises, when lighted, the power of capillarity, and continuously draws up the fluid fat to the accendible point, where the elements of the latter, carbon, oxygen, and hydrogen, are resolved by combustion into inflammable gases, which burn and produce flame. The external part *a e b* is the hottest, owing to its direct contact with the air, which supplies oxygen to complete the burning of those products which rise from the wick through the flame as faintly luminous matter, and in a state of partial combustion. As before said, this portion gives its maximum of heat at the level of *f f*. The coolest part of the flame, on the other hand, is at *a b*, and its blue color is due to the combustion of carbonic oxide and a small portion of carburetted hydrogen. The shaded cone in the centre is the sphere of unburned combustible, owing to the difficult access of the air to it; and surrounding it is the brilliant

Fig. 487.



portion, less favored with oxygen from the air than the exterior sphere of complete combustion on which it impinges.

When a current of air is directed through a blowpipe with a small, straight aperture against a flame, it drives the latter before it in a long, pointed, and conical projection. To produce a clean and uniform flame, the tip end of the blowpipe should barely penetrate the flame, Fig. 487, and when it is desired to give it volume, it must be slightly parted in the middle by drawing the tip of the blowpipe across it. In this latter case, too, the blowpipe should be directed at an angle of forty-five degrees across this channel. In blowing, the breath must be so regulated that the blast should be neither too strong nor too feeble; for, in the first instance, the excessive air cools the flame, and in the latter, the combustion is slow and imperfect.

"The long, narrow blue flame *a b*, which appears directly before the jet, is the same as *a b*, Fig. 486, although changed in form, being now concentrated into a small cylindrical space, whereas before it formed an envelope around the whole flame. Just before the point of this blue flame is the greatest heat, just as in a free flame, but with this difference, that, in the latter case, it formed a ring around the flame, while, in the former, it is concentrated into a focus. It is thus rendered sufficiently intense to fuse and volatilize substances which were not sensibly acted on by the flame in its usual state. On this is founded the whole theory of the intense heat produced by the blowpipe; the effect which would otherwise be distributed over the whole surface of the flame is concentrated into a small space, exactly as if the flame had been turned inside out. The surrounding illuminating portion of the flame prevents the heat from escaping.

"Long practice is required to know where the maximum of heat is, since different substances are differently ignited, and the light which they emit is often deceptive. A very intense heat is required when the fusibility of a substance is to be investigated, or when different metallic oxides, which are obstinate in parting with their oxygen, like the oxides of tin or iron, are to be reduced. But it is not a high temperature only which it is the design of the blowpipe to produce; there are other operations which require a less intense heat, and which, though diametrically opposed to each other, can be effected by the blowpipe. These are oxidation and reduction."

Oxidation.—"This takes place when the assay is heated, just

before the extreme point of the flame, when all the combustible particles are completely oxidized. The farther from the apex of the blue flame, the better the operation goes on, provided the heat be sufficiently intense; and it must be observed that a too high temperature often impedes the oxidation, especially if the assay be supported upon charcoal. Oxidation goes on best at a low red heat; and to this end the blowpipe jet must have a large aperture."

Reduction.—"This process succeeds best with a fine jet, which should not be inserted too far in the flame, since, in this case, a highly illuminating flame is produced, the elements of which, not undergoing complete combustion, do not take oxygen from the assay, which may be considered as being heated in an inflammable gas. If, in the course of the operation, the assay becomes coated with soot, it is a proof that the flame is too smoky, and, consequently, its heat is diminished. The blue flame was formerly regarded as the proper reducing flame; this is, however, untrue, for it is the brilliant portion of the flame which causes deoxidation; but the assay must be held in it in such a manner as to be surrounded by it on all sides and protected from contact with the air. It is to be remembered, that reduction is accomplished, not by the charcoal, but by the combustible atmosphere which surrounds the assay. The reduction which takes place at the points of contact of the assay and the charcoal would happen equally as well in the outer as in the inner flame.

"The most important matter is to be able to produce, optionally, oxidation or reduction; and this is soon acquired by practice. Oxidation is so easily performed that it is only necessary to be told how to do it. Reduction requires more experience, and a better knowledge of the management of the flame. It is an excellent exercise to fuse a small grain of tin upon charcoal, and raise it to a white heat, while keeping its surface brilliant. Tin has an attraction for oxygen so strong, that the moment the flame is changed in the least the metal becomes covered with an infusible crust of oxide of tin. The larger the globule of tin that the operator is able to keep fused in the metallic state, the more proficient is he in the management of the blowpipe and the flame."

The wick of the lamp must be cut evenly and free from fibres,

and the blast must be uninterrupted, more particularly in the reducing process.

Supports.—The substance under examination must be allowed to rest firmly upon a support, which should be such as will not fuse under a high heat, combine chemically with the fused body, or prevent its complete heating by rapid conduction. The supports in most common use are charcoal, and platinum either in the form of wire or foil.

Charcoal makes, for many operations, an excellent support, especially that kind of it which is made from well-grown pine wood, or the branches of the willow. It must be well charred, and that which snaps or smokes in the fire should be rejected. It is desirable that it shall be as free as possible from ashes, which nearly always contain a trace of iron and manganese; therefore dense and compact woods should not be used, as they give much ashes, and often contain a considerable amount of these oxides, which, by uniting with the fluxes employed, would give incorrect results. Straight pieces, free from knots, are to be sawed in the direction of the fibres, into oblong supports of the proper size. The saw for cutting the charcoal should have fine teeth and a blade of five inches length, three-eighths of an inch breadth, and one-sixteenth of an inch thickness. The assay is placed in a shallow concavity, made near one end of such a support by the borer or point of a knife; and upon this substance, so prepared, oxidation, reduction, and fusion are chiefly performed.

Sometimes the reducing property of charcoal, and the rapidity with which it is dissipated into carbonic acid, interfere with the result. In such cases, platinum in the form of foil or wire is used. A narrow strip, 3 inches long and ½ inch broad, is often advantageously employed for oxidation. The substance which is to be oxidized, is placed on it near one end, and heat is applied by the blowpipe flame upon its under side. Its conducting power is so inconsiderable, that the other end may be held between the fingers without inconvenience. Platinum cannot in general be used for reduction, as it forms fusible alloys with some of the metals; nor should sulphurets, arseniurets, &c., be heated in contact with it. When the strip is too short to be held between the fingers, it can be inserted in a piece of wood or charcoal, or be held between the points of a pincette. A small spoon of the same metal is

sometimes made use of; but in the majority of cases, the wire may be substituted for any other means.

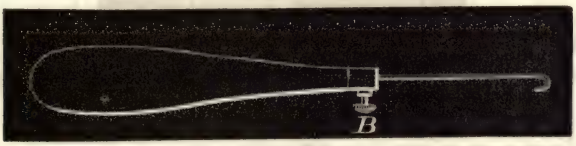
When platinum wire is used, it should be about 2½ inches long, moderately thin, and bent into a hook at one end, which serves as the support for the assay. This part is either heated for a moment in the flame, or moistened and dipped into the flux, whereby a small quantity becomes attached, which, when fused to a transparent bead by the blowpipe flame, becomes firmly fixed in its bed, and occupies the space within the curve. The side of the bead is then moistened, and a little of the assay is made to adhere to it.

Fig. 488.

Both are now fused together, and the appearance of the bead held in one or the other part of the flame, in reference to opacity, color, and other characteristics, can be distinctly seen from all sides, and in this way are colorations of the bead by metallic oxides particularly to be distinguished. The only objection to this hooked wire, occurs in the case of the use of *fusible flux*, which is apt to fall through it. Two or three additional turns of the hook will generally make a bed sufficiently close to prevent this salt from running through when fused.

The bead can be detached from the wire, when cold, by a slight blow with the hammer. If, after its removal, the wire is not left perfectly clean, a bead of soda may be fused upon it, and afterwards dissolved out, when it takes the impurities with it. In extensive investigations, by means of the blowpipe, a number of these wires should be provided.

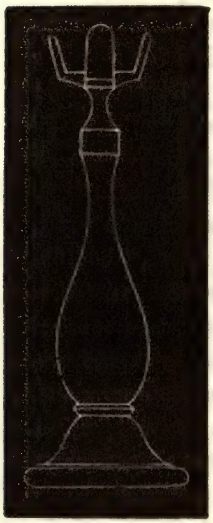
Fig. 489.



The wire may be held in the hand, either with or without a hilt; but it is more convenient to use the latter. It is nothing more than a turned piece of wood, Fig. 489, with a metallic socket on the end for receiving the wire, which is then fastened in by the screw B.

A support for cupels and small crucibles is shown by Fig. 490. It is a piece of turned wood, 3¼ inches long, with a brass wire, fashioned, as is seen, for receiving the cupel and holding it firmly during the action of the blowpipe. The handle allows the operator to change its position before the flame, merely by turning, raising, or lowering it, as may be necessary.

Fig. 490.

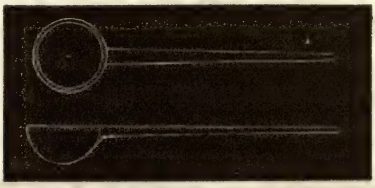


A small platinum spoon, from ¼ to ⅜ inches diameter, and of form shown by Fig. 491, will be required, as the containing vessel, in fluxing ores. It is made with a projecting strip from the bowl, by which it is adjusted in the handle, Fig. 489, on preceding page.

A well-polished ivory or platinum spoon, Fig. 492, about three inches long and three-sixteenths of an inch in breadth, will be necessary in weighing the powdered ore, and mixing it with the flux. The handle should, for greater convenience, be made in the form of a spatula.

Detection of Volatile Substances by means of the Blowpipe.—When volatile substances or gaseous products are to be tested

Fig. 491.



by means of this instrument, the body to be examined is usually exposed to heat in an open glass tube, which may be from two to

Fig. 492.

four inches in length, and from the twelfth to the third of an inch in diameter. The body is placed near to one end, and the blast

is directed upon it, while the tube (Fig. 493) is inclined more or less in proportion to the current of air, which is required to be passed through it. By such means, disengaged vapors may be sometimes recognized as they emerge from the upper end, and volatile matters condensed upon a part of the tube.

It is often necessary to deposit the substance in the angle of a curved tube, so as to prevent it from falling out. A tube so bent is shown at *b*, Fig. 494. Another modification is required where

Fig. 493.

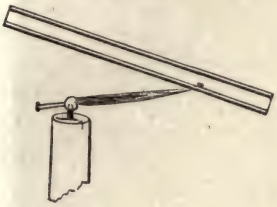
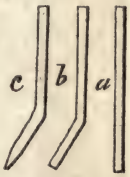


Fig. 494.



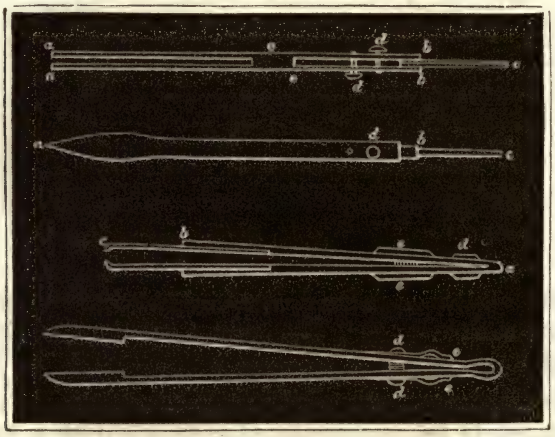
the access of much or any air would counteract the intention of the operator, by oxidizing the body. In such cases, the lower end of the tube is either completely closed, or drawn out to a fine orifice as at *c* in the same figure. A tube of this form is well adapted to the sublimation of selenium from a sulphuret, where the entrance of much air would oxidize it. Decrepitating substances should also be heated in tubes closed at one end, and should be so inclined as to avoid loss of particles. For such and many other purposes, tubes, Fig. 484, enlarged into a bulb at one extremity, are very appropriate.

All the glass tubes and vessels employed in this way should be perfectly free from lead.

The following instruments are also used in making examinations with the blowpipe;—steel forceps with the points made of platinum, for holding the assay in the blowpipe flame to ascertain its fusibility or other properties when exposed to an elevated temperature. The two upper drawings of Fig. 495 represent different views of an excellent forceps, capable of very general application. Two strips of steel, with narrow platinum points, *b*, *b*, are fastened in the middle by a piece of metal seen at *e*, *e*. These strips separated, as seen in the figure, constitute a double pair, one being at *a*, *a*, and the other at *c*. The platinum points, by

the elasticity of the metal of which the forceps are made, are always closed. To open them it is only necessary to compress with the thumb and finger the small projections with the button heads *d*, *d*, which are connected with the strips opposite to them. Upon relaxing the pressure, the assay is forcibly held between the points. The points *a a* are tempered, and are used for detaching exceedingly small fragments of the mineral.

Fig. 495.

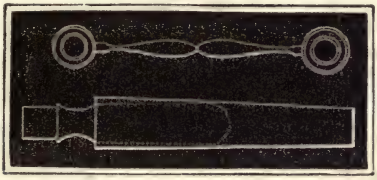


Another form of this instrument is employed, but its use is not quite as convenient as that of the one just mentioned. Its points *b c* are also of platinum, but curved a little, as represented in the figure. The legs are made of brass. The forceps is kept open by the elasticity of the metal, and closed by a double button *d*, which slides up and down in a slit cut in the legs. As brass is a good conductor of heat, two pieces of wood *e e* are fixed to the legs, by which the instrument is held, to prevent any inconvenience to the hand. Under this last forceps, is still another, made of iron, which can be used for a variety of operations, and which is not solely confined to this application. Substances to be held very firmly are placed between the points. It has a button *d d*, with a steel spring *d e*, to prevent the forceps from opening by the sliding back of the button.

Microscope.—A plano-convex microscope, with two lenses of different magnifying powers, is often useful in minute analysis, and one is represented in Fig. 496, which is made to fit in a small

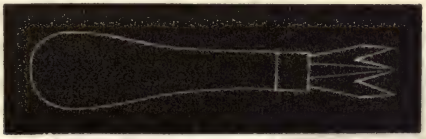
receptacle. By its aid, the minute structure of bodies, and fine colors imparted to the fluxes or to charcoal, which often deceive the naked eye, are examined.

Fig. 496.



Charcoal Borer.—A conical tube of tinned iron, with the margin filed to a sharp edge, for making cavities in the charcoal support, is often made to occupy a place in blowpipe apparatus. It answers very well as a case to contain a vial, as shown in the figure above. Another form of charcoal borer is presented in the annexed drawing, Fig. 497. "It is a four-sided pyramid of hard-

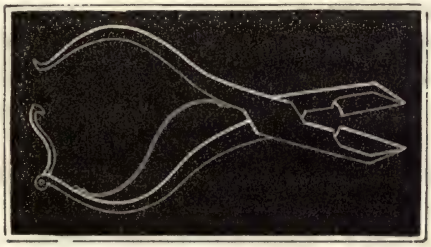
Fig. 497.



ened steel, with its sides filed away, so as to give it the form of a double chisel crossing at right angles." It is used for boring a round hole in the charcoal, by pressing it against the latter and turning it upon its axis until the cavity is sufficiently deep.

A pair of cutting pliers are used to clip off small particles of

Fig. 498.

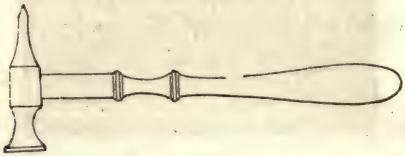


minerals and pieces of a metal or alloy for examination, and for many other purposes which will suggest themselves to the expe-

rimenter. A clasp is attached to the handles for the purpose of keeping them forcibly closed.

Hammer and Anvil.—A polished hammer of hardened steel, Fig. 499, with a square, even surface at one end, and the

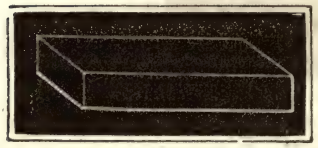
Fig. 499.



other terminating in an edge with sharp corners, is a very necessary implement. The flat surface is very applicable for flattening globules of reduced metals, and the edge for breaking off small pieces of minerals. Very small fragments can be broken off without doing any injury to the remaining portion, which is often kept as a specimen.

A necessary accompaniment to the hammer is the anvil, which is represented by Fig. 500, in a most convenient and compact form. It is made of steel, and is usually about three inches long, one inch in thickness, and five-eighths of an inch in breadth, and any one of its surfaces can be used. The substance to be broken up, or the metallic globule to be flattened out, is enclosed in thin paper, and having been placed upon the anvil, is struck with the hammer until the proper effect is produced. If the substance is reduced to powder, the paper prevents any of it from being scattered or lost.

Fig. 500.

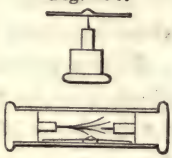


Mortar and Pestle.—These implements, made of agate, are of small size, and have been described at page 92. They should be hard and perfectly free from holes and cracks, or they will be liable to fracture, and to the filling up of their crevices with the powdered materials,—much to the detriment of future operations.

Electroscope and Magnetic Needle Case.—A cylindrical wooden box is used to contain Haüy's electroscope and a magnetic needle.

The former consists of the hair of a cat, insulated by being inserted in sealing-wax poured into the bore of a small glass tube. This tube is fastened in a wooden screw, which closes at one end of the case. It is so delicate that a very small quantity of electricity is discovered by its aid. On bringing it near to an excited body, it is attracted by it; but if negative electricity is developed in it, by rubbing or drawing it rapidly through the fingers, and it is then brought in proximity to the excited body, it will be attracted or repelled in accordance with the existence in that body of positive or negative electricity. In the screw at the other end (each one serving as a stand), is fixed a similar tube and sealing-wax to insulate a small steel pin, which supports a magnetic needle contained in the box. The needle is mounted with an agate cup to prevent friction as much as possible, when suspended on the point of the pin. In this condition, it is used to indicate the presence of iron when it exists in a mineral in an appreciable quantity, and also the magnetic condition of iron ores. Minerals, before and after being submitted to the action of the blowpipe, should be examined in regard to these properties.

Fig. 501.



Steel Magnet.—This is employed in the mode recommended by Haüy to ascertain whether the slightest trace of magnetic force exists in minerals, and consequently whether the metals in which that force exists are present. The experiment is thus performed. The magnet is placed at a small distance from a suspended magnetic needle, its north pole being directed towards that of the needle; it is then gently moved around the needle until the latter takes a position at right angles to its former place, owing to the repulsion of the same kind of magnetism. This repulsion, and the force of terrestrial attraction, which tends to make the needle return to its former direction, now hold the needle exactly balanced between them, so that the smallest disturbing magnetic force moves it out of its place. In this way, an amount of magnetic influence may be detected, which would not be sufficient to affect the needle in its ordinary state. In performing this experiment, care must be taken not to excite electricity in the mineral by friction, as that force might affect the result more or less.

A *knife* of good hardened steel is used for trying the comparative hardness of metallic bodies and minerals generally. It may be used as a charcoal borer, and if well magnetized can be substituted for the magnet. The point is used to take up the fluxes before mixing them in the palm of the hand with the mineral which has been pulverized for examination.

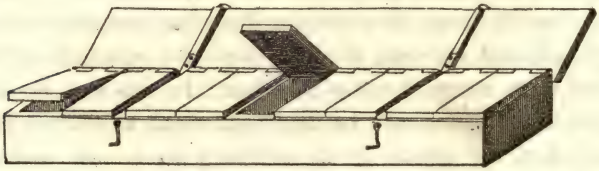
Files are convenient for detaching small particles of a metal which is to be investigated, cutting glass tubes, and for trying the hardness of bodies. They may be of different shapes, and should be kept clean, and out of the reach of corrosive vapors.

An *Edulcorator* or spritz, Fig. 428. This is used to wash the charcoal from the reduced metal. It is necessary to be very cautious in doing this when the metal is small in quantity, as the force of the jet may carry the latter away with the charcoal. A pipette or dropping-tube, made by drawing out in the flame of a candle or spirit-lamp one end of a glass tube to a small opening, can be used with less danger. The separation will be facilitated, by reducing to powder, in the agate mortar, for the charcoal adhering to the piece of metal, as the globule, if malleable, will be thus slightly flattened and made more distinctly visible.

Small capsules of porcelain, or *watch glasses*, are useful as temporary receptacles for the results of the experiments; such as specimens of reduced metal, the colored beads, &c., and for keeping separate different fragments of the minerals to be investigated.

A small pair of scissors, a pair of small tongs for holding crucibles, &c., over the spirit-lamp, a small capsule of platinum, a touchstone with needles of gold, and alloys of different standards for trying the fineness of gold, will each be occasionally required.

Fig. 502.



Box containing the Reagents.—As it is necessary to have the fluxes always ready for use, Gahn contrived a convenient and

portable box for the purpose, which is seen in Fig. 502. It is $8\frac{1}{2}$ inches long, $1\frac{3}{16}$ broad, 1 inch in height, and is divided into nine compartments to receive the different reagents. Each division has a lid nicely closing its particular box, so as to prevent any one substance from becoming mixed with the others. A common lid closes over these smaller ones, and is fastened to the box by two hooks. The cross pieces, which are permanently fixed to the large lid, fit into spaces between the second and third lids from each end, and serve to make them more secure.

The Reagents.—The reagents, which must all be chemically pure, are the following:

Carbonate of Soda, commonly called soda, which is much used to detect the presence of silica, to assist the reduction of metallic oxides, and generally, to determine whether a body unites with it to the production of a fusible compound.

Cyanide of Potassium.—This substance being very deliquescent, should be kept as free as possible from contact with humid air, and had better be placed in a small, tightly corked test-tube, which may have its place in one of the small compartments of the box.

As a blowpipe reagent, cyanide of potassium is highly useful; its action is indeed extraordinary. Substances like peroxide of tin, sulphuret of tin, &c. &c., which for their reduction with carbonate of soda, require rather a strong flame, are reduced with the greatest facility when cyanide of potassium is used. In blowpipe experiments we always use a mixture of equal parts of carbonate of soda and of cyanide of potassium, since the latter alone fuses too easily. This mixture, besides its more powerful action, has another advantage over carbonate of soda: it is with extreme facility imbibed by the porous charcoals, so that the purest metallic globules are obtained.

Biborate of Soda.—This salt, which is commonly called borax, is used to facilitate the fusion of very many substances. When melted with the metallic oxides, its bead assumes a great variety of colors, which furnish excellent indications of the presence of the metals.

Phosphate of Soda and Ammonia.—This substance, called also microcosmic salt, phosphorus salt, and fusible flux, is of very general application, and as it dissolves most of the metallic

oxides with great readiness, the colors produced in its bead are, if possible, more brilliant and characteristic than those made with borax.

Nitrate of Potassa, or saltpetre, is used to assist in the oxidation of metals, as it yields up its oxygen very readily when exposed to heat.

Bisulphate of Potassa in solution, is used to indicate lithia, boracic acid, nitric acid, fluohydric acid, bromine, and iodine; and also for the separation of baryta and strontia from other earths and metallic oxides.

Vitrified Boracic Acid (glass of borax), is used to detect the presence of phosphoric acid; also small portions of copper in alloys of lead.

Fluoride of Calcium (fluor spar), when mixed with bisulphate of potassa, serves to detect lithia and boracic acid. Alone, it is a test for gypsum.

Sulphate of Lime, or gypsum, in the form of plaster of Paris, is sometimes used as a reagent with fluoride of calcium.

Nitrate of Cobalt.—This very valuable test is used in a somewhat concentrated solution.

Alumina heated in the oxidating flame, after being moistened by a drop or two of this solution, acquires a beautiful pale blue color, magnesia a rose-red tint, and zinc a bright green. The solution is contained in a phial similar to the one represented in Fig. 503. The glass stopple, tapering to a point, descends into the solution, so that on withdrawing it, a small quantity adheres to its extremity. Berzelius uses a cork stopple with a platinum wire flattened out in the form of a spoon, the end of which is immersed in the solution. The phial may be of such a size as to be conveniently received in the charcoal borer, Fig. 496. Oxalate of cobalt may be made to take its place, and as it is used in powder, it is often of more convenient application.

Fig. 503.

Nitrate of Nickel in solution, or *Oxalate of Nickel* in powder. The oxide of nickel gives a brown color to soda glass, while potash, if melted with a substance containing it, acquires a bluish-purple color. A bottle similar to the one just described may contain the solution of the nitrate.

Lead, very pure, and especially free from silver, is used in cupellation.

Bone ashes are employed in cupelling metals containing gold and silver, and some of the ores. The cupels are prepared by moistening a small quantity of the ashes, mixed with a little soda-salt to make it coherent, and by kneading the mass in the palm of the left hand to the consistence of a stiff paste. A cylindrical hole made in a piece of charcoal is then filled with the paste, and after the surface is smoothed with the small agate pestle, a slight depression is made in the centre, sufficiently large to hold the metal or mineral to be cupelled, together with a small quantity of the proof lead. The cupel is slowly dried by heating it carefully in a stove or over the flame of a spirit lamp. The assay with the lead is then placed on the cupel and submitted to the action of the exterior or oxidating blowpipe flame. By the influence of this, the lead is oxidized, and the fused litharge so formed, is absorbed by the bone ashes, while the silver or gold is left behind in the form of a brilliant globule; which, before its complete purification, exhibits the iridescence formerly described under CUPELLATION. Plattner describes a convenient instrument for making the cupels.

Oxide of Copper is used for the purpose of detecting chlorine.

Silicic Acid, when melted into a fusible glass with soda, is a test for sulphur or sulphuric acid. The assay must, however, not contain it.

Silver, in the form of wire or foil, is made use of for ascertaining the presence of sulphuret of potassium, or any other soluble sulphuret.

Tin Foil sometimes assists in the reduction of metallic oxides, which are dissolved in a bead of one of the fluxes, and by its use we sometimes get a more satisfactory result than is obtained without it. For instance, when a small quantity of copper is dissolved in a bead of borax, or of microcosmic salt, and the glass is treated in the reducing flame, it sometimes becomes ruby-red and opaque. But if the amount of copper is so small that the reducing flame cannot produce this result, a little tin added to the bead, and heated with it, makes the proper appearance evident immediately upon its cooling.

Iron wire, which is generally that metal in its purest state,

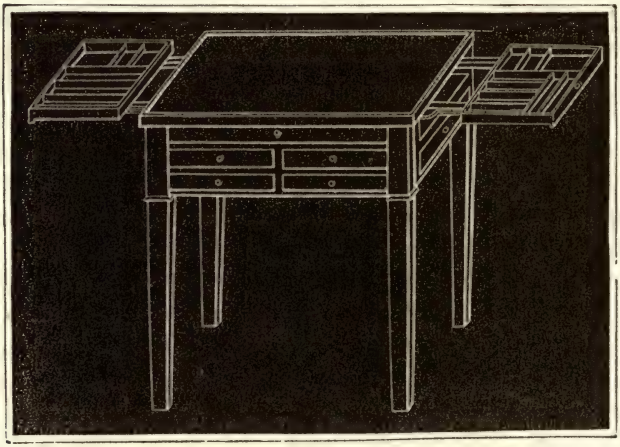
precipitates some other metals from the different fluxes, or separates therefrom sulphur and the fixed acids. It is also used to reduce phosphoric acid to phosphorus, which, combining with iron, forms a white brittle metallic globule, the phosphuret of iron.

Besides the above-mentioned tests, it is proper to have *Formate of Soda*, which, when anhydrous, is used to detect arsenic in oxide of antimony. Test papers colored with litmus, Brazil wood, and turmeric, are also convenient.

The substances mentioned in the foregoing list as reagents, are all of those which are essential to the completeness of the blowpipe apparatus. While, however, occasions may arise for the use of any or all of them, the great majority of examinations with the blowpipe can be made with the aid of but a few, and the possession of the first four or five upon our list, with the fluid nitrate of cobalt and the metals referred to, may be considered as quite enough to make the manipulator competent to pursue ordinary investigations.

Blowpipe Table.—In the laboratory all the instruments essential to the expedition of blowpipe analysis are placed within convenient reach of the operator. For this purpose Gahn's table,

Fig. 504.



which has drawers both in the side and front, will be found very useful. The side drawers are shown in Fig. 504, drawn out from their usual position. The right hand drawer contains the appa-

ratus most frequently used, and the left that which is less often required. The lamp, blowpipe, fuel, wick, and other necessaries of a rougher kind, occupy those in front.

The drawers are fitted with receptacles for each and every article, so that they may rest securely, when moved; and they can therefore be readily formed into a travelling case. Chests, however, for this purpose, are specially constructed with great regard to economy of space and number of conveniences. Those made by Lingke, comprise, in a case of about twelve inches square, and admirably arranged with drawers and apartments, all the implements and accessories for quantitative as well as qualitative blowpipe assays, including a compact and very delicate balance with weights.

Having fulfilled our duty of describing the more practical points of blowpipe operations, we refer the reader, for all other necessary information, to the comprehensive treatises of Berzelius and Plattner, both of which have been translated into English, the first by Whitney and the second by Muspratt.

The annexed tables will also serve, conveniently, both as a guide and for reference, in practical exercises. For testing by them observe the following directions:

Fuse a globule of microcosmic salt on platinum wire; add a small quantity of the substance to be tested, and again heat to redness in the oxidizing flame; observe the color of the globule, and allow it to cool, and again note its color. The substance may thus be referred to one of six classes. If the globule is colorless, add a further quantity of the substance to be tested, and treat as before, in order to ascertain if the globule will become opaque on saturation. Then heat the same globule in the reducing flame, and again note its color. Repeat the operations with a globule of borax, and, if necessary, apply the special tests given under the head of Remarks to Individualize.

HERAPATH'S TABLE FOR TESTING BY THE BLOWPIPE.

With Microcosmic Salt, in the Oxidizing flame (O.F.)	With Microcosmic Salt, in the Reducing flame (R.F.)	With Borax, in the Oxidizing flame.	With Borax, in the Reducing flame.	Substances.	Remarks.
Bead, *blue* (very deep); hot and cold.	Bead, *deep blue.*			1. Oxide of cobalt.	
Bead, *green; reddish* while hot.	Bead, *bright green.*	Bead, *green.*		2. Chromium, oxides of.	*Compounds containing chromium, when fused with nitre and potash in a silver crucible, yield a yellow mass, containing chromic acid.*
Ditto; *bluish green* when cold.	Bead, *brownish red.*			3. Copper, oxides of.	*Compounds containing copper, when fused with soda on charcoal, yield metallic copper. Copper is malleable, and red in color; is acted upon by nitric acid, giving a solution which is turned blue by an excess of ammonia.*
Ditto; *yellow* while hot.	Bead, *bright green.*	Bead, *yellow.*		4. Uranium, oxides of.	
Bead, *amethystine* when hot; *pale* when cold; the color is rendered darker by nitre or borax.				5. Manganese, oxides of.	*Compounds containing manganese, when fused with nitre and potash (see 2), yield a bright green mass (mineral chameleon).*
Bead, *yellow.*	Bead, *green; brownish* while hot.	Bead, *yellow.*	Bead, *green.*	6. Vanadium, oxides of (vanadic acid).	On charcoal are only partially reduced; *with soda, on ditto, fuse, and are absorbed.*
Bead, *yellow;* when the oxide is in excess, *opalescent.*	Bead, *gray,* from reduced silver.	Bead, *colorless.*	Bead, *gray.*	7. Silver, oxides of.	Compounds containing silver, on charcoal in R. F., alone or with soda, are easily reduced. *Silver is easily fused, silvery white in color, malleable, and not oxidizable, B.B.; is soluble in nitric acid, and the sol. yields a white curdy precipitate with hydrochloric acid.*

Bead, *yellow;* almost *colorless* when cold; a great excess of oxide produces an enamel.	Bead, *gray*, from reduced bismuth.	Bead, *colorless.*	Bead, *gray.*	8. Bismuth, oxides of.	Compounds containing bismuth are easily reduced on charcoal in R. F. *Bismuth is pinkish-white in color, and rather brittle; is easily oxidized, giving a brownish-yellow oxide, and very broad areola. It is sol. in nitric acid, and yields a solution which furnishes a white precipitate on the addition of water.*
Bead *red* or *yel.-red* while hot; *pale*, when cold.	Bead, *colorless* when cold, but *red* when hot. If tin is added it becomes first gray and opaque, and then colorless.	Bead, *pale* when cold; fused with a little nitre, the color is changed to *blue.*		9. Nickel, oxides of.	Easily reduced on charcoal: color of metal, white; metal, dif. fusible, and attracted by the magnet. *It is sol. in nitric acid, and the solution becomes light blue on the addition of ammonia in excess.*
Ditto.	Bead, *colorless.*	Bead becomes *opaque* when heated in the intermitting flame.		10. Cerium, oxides of.	Are not reduced on charcoal.
Ditto.	Bead, *green.*	Bead, *bottle green.*		11. Iron, oxides of.	B.B. in the O.F., compounds containing iron give a black magnetic scoria; *this, when finely powdered, is red in color.* On charcoal, in R. F., they yield a gray mass of metallic iron, which is highly magnetic.
Beads nearly *colorless*, or rendered dark-colored and opaque by particles of reduced metal. [At a high temperature, 12 separates as a metallic globule, and the bead becomes colorless.	As in the oxidizing flame.	As with Microcosmic salt.		12. Gold, oxides of.	Are easily reduced, B.B. Metal less fusible than silver; *soft and malleable; yellow in color*, and not oxidizable, B.B. It is not acted upon by nitric or hydrochloric acid, *but is sol. in aqua regia, even in the cold, giving a yellow sol. A drop or two of the latter, when smeared on a porcelain plate, and heated to redness, gives a fine purple metallic stain.*
				13. Platinum, oxides of.	When the spongy reduced metal is strongly pressed in a pestle and mortar, it becomes bright and splendent. Platinum is insol. in *cold* nitro-muriatic acid.

With Microcosmic Salt in the Oxidizing flame (O.F.)	With Microcosmic Salt in the Reducing flame (R.F.)	With Borax in the Oxidizing flame.	With Borax in the Reducing flame.	Substances.	Remarks.
				14. Palladium, oxides of.	When the spongy reduced metal is strongly pressed in a pestle and mortar, it becomes bright and splendent. Palladium is insol. in *cold* nitro-muriatic acid.
				15. Rhodium, oxides of.	Ditto.
				16. Iridium, oxides of.	Ditto.
Bead, *colorless*. When added in excess, these bases give beads which are *milky white* when cold; with oxide of lead, the bead is *yellowish* while hot.	As in the oxidizing flame.	As with Microcosmic salt.		17. Lead, oxide of.	Compounds containing lead are easily reduced by soda on charcoal, in R. F. *Lead is bluish-white, very soft and malleable, easily fusible, and yields a broad areola and yellow oxide on charcoal in O.F.*
Bead, *colorless*. When added in excess, these bases give beads which are *milky white* when cold; with oxide of lead, the bead is *yellowish* while hot.				18. Zinc, oxide of.	Compounds containing zinc are reduced with some difficulty, B.B. Zinc itself is bluish-white in color, *and rather brittle; is easily oxidized, giving off B.B. (in O. F.), white fumes of oxide of zinc, and yields a broad areola on charcoal. The oxide is yellow when hot, but white when cold; it turns green when moistened with a weak sol. of nitrate of cobalt, and again heated B.B.*
Ditto.	As in the oxidizing flame.	As with Microcosmic salt.		19. Cadmium, oxide of.	Compounds containing cadmium, when heated on charcoal, B.B., *give a broad areola of brown oxide of cadmium.*
Ditto.				20. Baryta.	Chloride of barium in alcohol gives a *green flame*. Anhydrous baryta is infus.; the hydrate and carb. fuse, B.B. — All these earths emit a glaring white light when heated on charcoal, B.B.
Ditto.				21. Strontia.	Chloride of strontium in alcohol gives a *red or scarlet flame*. Hyd. of strontia is fus.; the carb. only partially fus. — All these earths emit a glaring white light when heated on charcoal, B.B.

Bead, *colorless.*	When added in excess, these bases give beads which are *milky white* when cold; with oxide of lead, the bead is *yellowish* while hot.	As in the oxidizing flame.	As with Microcosmic salt.		22. Lime.	Chloride of calcium in alcohol gives a *dull red flame.* Lime and its hyd. are infus.; so also the carb.; but the latter is easily converted into caustic lime. All these earths emit a glaring white light when heated on charcoal, B.B.
Ditto.					23. Magnesia.	When moistened with a sol. of nitrate of cobalt, it becomes *flesh red*, B.B.
Ditto.					24. Glucina.	Is infus., B.B. Compounds containing glucina, give a dark-gray slag with nitrate of cobalt. (See 13.)
Ditto.					25. Thorina.	Is infus., B.B. Compounds containing thorina give a dark-gray slag with nitrate of cobalt. (See 23.)
Ditto.					26. Yttria.	Ditto.
Ditto.					27. Zirconia.	Ditto.
Ditto.	Even when saturated and cold; with oxide of antimony, antimonious acid, tungstic acid, and titanic acid, the beads are *yellowish* while hot; with molybdic acid, *green.*	Bead, *dark blue* while hot; *green* when cold.			28. Molybdic acid.	On charcoal, fuses and is absorbed; reduced in form of small globules by strong R.F. It colors the flame green.
Ditto.		Bead, *yellow* while hot; *violet* when cold. If iron is present, red; the addition of tin destroys the red coloration.			29. Titanic acid.	Is not reduced on charcoal, even with the assistance of soda; the glass is not absorbed.
Ditto.		Bead, *blue.*			30. Tungstic acid.	Only partially reduced on charcoal; a mixture of metallic tungsten and yellow oxide is often obtained with soda, in R.F.
Ditto.		Bead, *gray*, from reduced tellurium.			31. Tellurium, oxides of.	On charcoal, is reduced with effervescence; the metal volatilizes, and coats the charcoal with white oxide.
Ditto.		Bead, *gray*, from reduced antimony.			32. Antimony, oxides of.	On charcoal, in R. F., give metallic globules of antimony. The metal *is brittle, crystalline*, and *white in color;* is volatilized in the O.F., imparting a greenish-blue color to the flame, and gives off white fumes of oxide of antimony.

With Microcosmic Salt in the Oxidizing flame (O.F.)	With Microcosmic Salt in the Reducing flame (R.F.)	With Borax in the Oxidizing flame.	With Borax in the Reducing flame.	Substances.	Remarks.
Bead *colorless.* Even when saturated and cold; the metal is volat.	As in the oxidizing flame.	As with Microcosmic salt.		33. Mercury, oxides of.	Compounds of mercury, when heated in a tube with tin or iron filings, yield a *gray sublimate of metallic mercury, which, when examined by a lens, is seen to consist of minute globules.*
Ditto.				34. Arsenious & arsenic acids.	Arsenical compounds, when heated in a tube with black flux or cyanide of potassium, yield a *steel-gray mirror-like sublimate of metallic arsenic.* This, when heated in a current of air, *diffuses an alliaceous odor*, and yields a sublimate of arsenious acid, *crystallized in brilliant colorless octohedra.*
Ditto, even when saturated and cold.	As in the oxidizing flame.	As with Microcosmic salt.		35. Tin, oxides of.	Are easily reduced on charcoal, with soda, in R.F. *Metal very fusible, malleable, silvery white in color;* oxidizes in O.F., and gives a *non-volatile white oxide coating the surface of the fused metal; areola, none.*
Bead, *colorless.* Even when saturated and cold.	As in the oxidizing flame.	As with Microcosmic salt.		36. Tantalic or Columbic acid.	Is not reduced on charcoal.
Ditto.				37. Alumina.	Compounds of alumina, when moistened with nitrate of cobalt, *give a beautiful blue enamel* before the blowpipe.
Ditto.				38. Soda.	Compounds of soda communicate a *bright yellow color* to the blowpipe flame.
Ditto.				39. Lithia.	Compounds of lithia color the flame *red*, if no soda is present.
Ditto.				40. Potash.	Compounds of potash color the flame *pale lilac, or violet*, if no soda is present.
Ditto.				41. Ammonia.	Compounds of ammonia, when heated with lime or potash, *give off ammoniacal gas.*

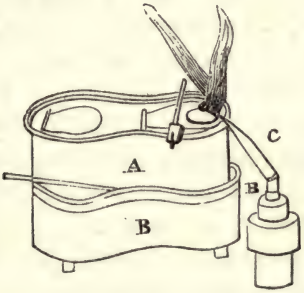
CHAPTER XXX.

GLASS-BLOWING.

THE ability to work glass over the lamp or blowpipe-flame is a very desirable accomplishment for the chemist, as it enables him to fashion for himself, and in accordance with his own judgment, such micro-apparatus as is constantly in demand during experimental research. The inconvenience and expense of having a large stock of delicate glass instruments always at hand, and the difficulty of obtaining such at all times, especially in localities distant from the cities, render instruction in the art doubly desirable. On these accounts, we think it proper to devote a chapter to a few illustrations of the processes by which tubes are bent, closed, rounded, widened, and drawn out, and by which bulbs are blown and joints sealed.

The two principal pieces of apparatus required are a lamp and a table blowpipe. The latter, as well as its management, have already been written of at page 69. The former, known as Danger's "Glass-blower's Improved Lamp," of form shown by Fig. 505, is of sheet brass, and rests upon a tray designed for the

Fig. 505.



reception of any overflow of oil. These lamps are fitted with an arrangement by which the wick may be raised or lowered, and the flame consequently enlarged or diminished as desired: an accompanying hood, or short conical chimney over the burning wick, serves to increase the heat and to protect the eyes from the smoke and flame.

The wick may be made of common candle-wick, divided into lengths of proper dimensions, and stranded together, so as to form a diameter of about three-fourths of an inch. This bunch is placed in that part of the lamp intended as its receptacle, and should only protrude above the oil about the third of an inch. It should be kept constantly supplied with oil or fat, and free from "snuff" by frequent trimming. To obtain the highest possible heat from the lamp, the vent-hole in the nozzle C of the blast table must be very small compared with the capacity of the wind chest, and when it is desired to lessen the power of its flame, as may be necessary in the heating of small tubes, the force of the blast must be diminished.

The fuel may be olive, lard, sperm, or tallow oil;—the latter, however, being preferable on account of its giving a hotter flame. In case of the absence of a lamp of this sort, any common metallic vessel, of proper size, may be fitted for use, upon the blowpipe-table, by training up upon, and allowing to overhang its side, a thick bunch of wick. This may be kept in place, and its flame, at the same time, be prevented from descending too far, by encircling it with a tin or other metallic tube, or a coil of wire, which may be temporarily connected with the sides of the vessel, so as to answer all the intentions of support and the conduction off of the excess of heat.

If the experimenter cannot have access to a properly made blowpipe table, he may, in a very short time, construct a substitute himself, which, however rough, will enable him to carry on nearly all the operations of glass-blowing. A hollow reed or piece of cane-angle, about a foot in length, may be firmly fixed in a circular hole, drilled near the edge of a common table, and which is just large enough to admit and hold it firmly in its place. This may have adapted, by means of cement, plaster, or putty, to its upper end, a nozzle of metal, or of glass drawn out to the proper sized orifice, or one made of a piece of tobacco-pipe of the requisite calibre. A bladder of the largest size, or bag of caoutchouc, furnished with two openings upon the same part of its circumference, is now firmly attached to the bottom of this tube, in one of which a similar piece of reed, long enough, however, to reach from the operator's knees—while sitting—to his mouth, having been inserted and tied into the other opening. That end

of this last-mentioned tube which is within the bladder, should be provided with a valve, like that of a cupping-glass, made by placing loosely over it, a long strip of oiled silk, of the diameter of the tube, folding the ends upon the body of the reed and tying them firmly to it by waxed thread. This valve admits the passage of air into the receptacle, but will not allow its return through the same orifice, so that pressure upon the bladder will compel its exit through the nozzle of the tube which is fixed in the table. If, then, the operator, sitting near the table, with the bladder hanging between his knees and the loose tube fixed in his mouth, inflates the former, and then presses upon it uniformly with his knees, a continuous current is expelled from the nozzle upon the flame of the wick placed directly above it. A repetition of the inflation only becomes necessary when the bladder is nearly emptied of its contained air. The inflation of this home-made apparatus is scarcely, if at all fatiguing; and it gives to the glass-blower the unincumbered use of both his hands. Russia lamps, and similar implements, described in Chapter XI, may, in many cases of glass-blowing, be substituted for the blast-table and Danger lamp.

Fig. 506.

The position of the jet upon the top of the table, and that of the operator before it, are shown in the annexed drawing.

When it is desired to use the gas flame, the straight jet and Argand burner, as is shown in the annexed drawing, are employed. It is still better, in ordering a blast-table, to have prepared a movable jet, with ball and socket joint, suitable for giving the flame a horizontal or vertical direction, as may be required.

The other implements are an iron piercer with wooden handle, Fig. 507, a cone of biscuit-ware or soap-stone, Fig. 508, for

Fig. 507.

Fig. 508.

Fig. 509.

widening the necks of tubes, a small pair of brass tongs, Fig. 509, for fashioning bulbs, &c., a small piece of smooth hoop-iron, styled the *marver*, a hardened cast-steel knife, and one or two three-cornered files for cutting tubes and rods.

In addition to the above, the table should be supplied with a stock of tubes and rods, of assorted diameters, and made of glass free from lead. They should, moreover, be very uniformly regular throughout, and exempt from flaws or striæ.

To prevent the table from being incumbered and uncleanly, the

Fig. 510.

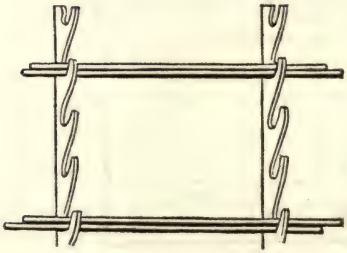
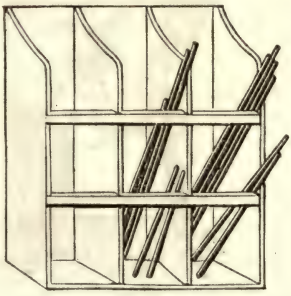


Fig. 511.



long tubes should be kept in a rack like that shown by Fig. 510, and the shorter pieces in one as presented by Fig. 511.

Before commencing operations, the wick must be evenly trimmed and parted in the middle, so that when the jet is placed opposite in the rear, and in proper relation, it may drive the flame forcibly in advance, but not of too great length, else it will become smoky.

Tubes can very readily be severed, or divided into lengths, by scratching them with a file, and breaking asunder as at Fig. 519. For large tubes, the scratch must extend entirely around the circumference.

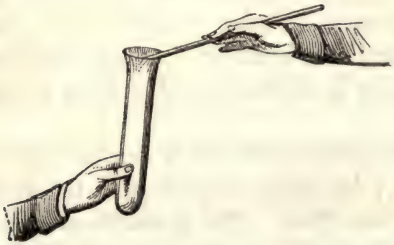
Vessels of larger diameters, such as necks of retorts, and the like, require the use of a diamond spark. According to Mr. Nasmyth, coke has the property of *cutting* glass, and can very well be substituted for the diamond.

When the scratch of the file is insufficient to effect a smooth division, it must be moistened and then traced with a heated wire or pastile. A heated wire will also divert a crack in a glass vessel to any desired direction.

The tubes or rods, previously divided into the required length, should always be wiped perfectly dry before being subjected to the action of the flame, and then carefully and gradually heated, the uniform diffusion of the heat being effected by keeping them revolving;—these precautions, which are always to be observed, prevent breaking from sudden and unequal heating. After being heated, they must be removed gradually from the fire, and laid upon a piece of charcoal, so as to become annealed, as it were, by gradual cooling.

The most simple and easily performed of all the operations of

Fig. 512.



glass-blowing, is the rounding of edges, which is readily done by heating them to softness in the flame during constant revolution

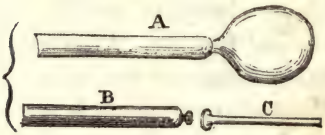
of the tube between the thumb and three fingers, which support it. This operation, by which the edges of tubes and rods are smoothed, is also preliminary to that of widening the mouth of a tube, a test-tube for example, which is done by spreading it while hot, as shown in Fig. 512, by means of the iron piercer, or, better, the biscuit cone, either of them being previously warmed, and then carried round the opening with an outward pressure.

Tubes Cemented.—Tubes or rods are also cemented together by softening their ends and blowing gently through them at the moment of junction. Care must be taken to hold them firmly and perfectly even, as shown in Fig. 513, and to retain hold of the joined tube until it has entirely cooled, else it may bend by its own weight at the heated part, and thus become crooked.

Fig. 513.

If the tubes to be cemented are of unequal diameters, the wider one must be closed at its end, then heated in the flame and quickly blown into a thin bulb, as shown by A, Fig. 514. This bulb is then broken off so as to leave only a shoulder at the mouth B. This being done, the end of the small tube is next blown in the same manner, as at C, and the two shoulders are then to be cemented as before directed.

Fig. 514.



Rods are cemented together by partially fusing their ends and bringing them carefully together, and pressing them until they adhere. The welding is then completed by heating the new joint, during which process, in order to impart shape, the rods must be kept rotating, and be alternately drawn out and brought together, until the junction is as smooth and uniform as any other part of the surface.

Tubes Bent.—Very small tubes can be bent over the spirit lamp, Fig. 151; but larger ones require the force of the blowpipe-flame to heat them. The operation of bending consists in heating the tube to dull redness, about an inch on either side beyond the point of the intended curve, by revolving it in the flame, and just at the commencement of softening, in making an

angle, by bending it dexterously, but very gradually, in the desired direction until it assumes the required form. In order to prevent a wrinkled, and consequently very fragile elbow, Fig. 515, it is necessary that the operation of bending shall be accomplished by progressive steps, as illustrated by Fig. 517. Closing the

Fig. 515.

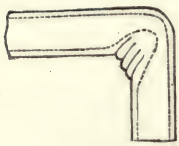
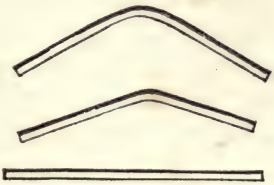


Fig. 516.

Fig. 517.



tube at one end, and blowing gently into the other, during flexion, so as to produce internal pressure, will also counteract any tendency to malformation.

Drawing Out.—When a tube is to be drawn out, either as preliminary to further working, or in the preparation of nozzles for washing-bottles, or other purposes, one of the proper size is taken, at the ends, between the thumb and index of each hand, and along its length with the other fingers, and kept revolving gradually over the flame until it becomes red, and commences to soften at the heated part. It is then taken from the fire and drawn apart, as shown in Fig. 518. In this way also stirring-rods are

Fig. 518.

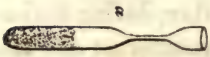
pointed, and when the tips of either tubes or rods thus wrought are to be smoothed, it is only necessary to divide or break across the centre of the part drawn out, and to heat the surfaces in the flame until they soften and become round. The proper mode of severing glass rods or tubes, is first to make a deep scratch with a three-cornered file in the spot where separation is required, and then, after grasping them as shown in Fig. 519, by gently breaking them apart.

Fig. 519.

The tube must not be kept in the fire too long, nor yet drawn out too rapidly. When the tube or rod is too short to be divided, it may be drawn out at either of its ends by means of a *punto*—a piece of glass rod which is heated to softness and cemented to the other as a handle.

Tubes Closed.—Very small tubes may readily be closed by softening their edges over a flame, and rotating them until they unite and adhere. Tubes of larger size are treated in the same way, but to facilitate their closure, occasional pressure of the hot end against the back of the tool, Fig. 509, and sometimes gentle blowing through the open end, are required. Tubes also are closed hermetically by drawing out one end, as shown in Fig. 520, by then scratching with a file and breaking asunder the part *a*, and finally by closing the small orifice by fusion in the flame.

Fig. 520.



Drawing Out and Closing.—When it is desired to form a vessel like a test-tube, a tube of the required diameter is drawn out, as at Fig. 521, and then cut asunder at *a*. The two pieces thus formed, serve to make two test-tubes. For that purpose, it is necessary to heat the smaller end of each to softness, and imme-

Fig. 521.

Fig. 522.

diately upon removal from the flame, to blow cautiously and slowly into the open extremity until the closed end assumes a uniform spherical shape. Sometimes it is necessary to repeat the heating and blowing, in order to fashion the bottom perfectly, as seen in Fig. 523. If the piece of glass is only long enough to form one tube, its end can be drawn out by attaching a punto, as before described, and now shown at *b*, Fig. 522. This punto, or

glass rod handle, serves also to remove any redundant glass, it being only necessary for that purpose to heat the closed end highly, to apply the punto a little less heated, and after collecting upon its end as much of the surplus melted glass as is required to make the bottom thin and capable of supporting sudden changes of temperature, to draw it off. This manipulation requires some dexterity, which is, however, easily acquired by slight practice. If at one heating and gathering, the bottom has been reduced to the proper thinness, it may be heated anew, removed from the fire, and then by slow and gentle blowing, through the open end, the bottom may be blown out to roundness. The mouth of the tube is then finished as directed at page 605, Fig. 512.

Fig. 523.

Lateral Attachments.—To attach a tube to the side of another is somewhat difficult. For this purpose, the tube with which the junction is to be effected is closed at one end and heated at the desired point, such as *b*, Fig. 524, to high redness. To this hot part a glass rod, or punto *c*, slightly heated, is attached and drawn out, as shown in the figure. When the glass has cooled,

Fig. 524.

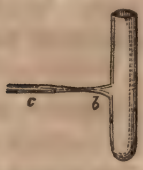


Fig. 525.

cut off the new joint at *b*, heat again in the flame, and widen its mouth with the tool, Fig. 507, to the size of the diameter of the tube which is to be joined with it. This having been done, the tube is to be attached as directed at page 606. Fig. 525 shows the joint perfected.

Another mode is to heat and close the drawn out end, and to blow forcibly through the tube until the bulb, thus formed, bursts. All the remains of the thin glass bulb being broken off, a protruding aperture is left, to which the lateral tube may be cemented, in the usual way, by heating the edges of the ends of the two tubes to be united, joining them in the flame with slight compression, heating the joint to redness, and then slightly blowing, to give form and prevent cracking.

To Blow Bulbs.—To form a bulb at the end of a narrow tube,

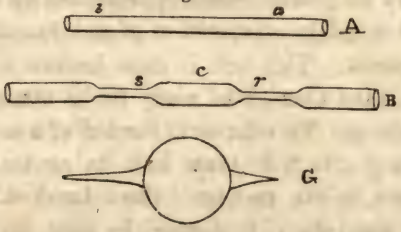
it is only necessary to continue heating it after closure until it commences to soften, and then, immediately upon its removal from the flame, to blow into the open end, as in Fig. 526, slowly, until the heated part expands to the proper size and shape. Care must be taken to heat the tube to a sufficient extent, so that there may be enough glass softened to give a bulb of the required size;—moreover, during both the heating and blowing the tube must be kept slowly rotating between the fingers, so as to prevent an accumulation of the melted glass, by its own weight, in any one part.

Fig. 526.

To blow a bulb in the middle of a tube, the latter must be heated at its centre during constant but slow rotation between the fingers, and then carefully blown into at one end, whilst the other is closed with the finger, a cork, or a piece of wax. The pressure of the air within expands the hot glass into a spheroid, regular or irregular in form, according to the care and skill of the operator. The part of the tube to be expanded must be heated uniformly, and kept in constant and slow revolution during both the heating and blowing.

In the fashioning of certain glass-tube apparatus, it is sometimes necessary to blow the bulbs separately, and to attach them afterwards to their adjacent parts;—the bulb is then formed as follows. Take a glass tube A, Fig. 527, of the required dia-

Fig. 527.



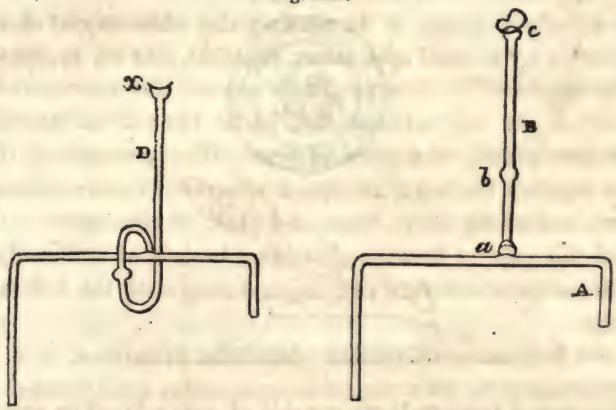
meter and length, heat it at the points *a* and *b*, and draw it out in two places, as shown at *r s* in B. When the tube has cooled, divide it at the attenuated parts *r s* with the file, as directed at page 608, Fig. 519, and close one end of one of the pieces in the flame. Then hold it by the other end, which is drawn out, heat

it to redness, and fashion the bulb by blowing, as above directed, until it assumes the shape of G. It is then cemented to the other parts of the apparatus, as directed at page 606, the previous widening of the drawn-out parts being performed as at Fig. 512.

Thermometer bulbs are made by expanding, as above directed, the heated end of tubes with a capillary bore.

To Make a Welter's Tube.—By way of illustrating the different operations of fashioning glass tubes over the blowpipe flame, we will go through the different stages of manufacture of the safety-tubes of Welter. A straight tube is first bent into form, as at A, Fig. 527, and the flame is directed upon *a;* as

Fig. 528.



soon as the glass softens at that point one end of the tube is closed with the finger, and the other is blown into forcibly, so as to form the very thin, brittle bulb represented by the dotted lines. When the tube is thick, a repetition of the heating and blowing is required. This bulb is then broken off, and the bent tube, thus formed, is ready to be attached to the straight tube B. This latter is formed of a separate tube, and having a bulb *b* blown into its centre, is cemented to A at *a*, in the manner before directed. The funnel top of the tube B, is formed by first blowing a bulb *c* on its upper end to extreme thinness, removing it with the file and cementing a bulb, with open mouth, as at *x* in D. The S form is given merely by bending B in the proper direction.

Fig. 529.

Instead of an open *bulb* at the top of the D tube, a small funnel is cemented to it, as in the fashioning of funnel-tubes, Fig. 529.

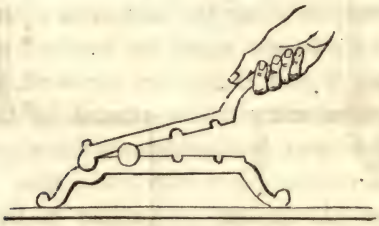
CHAPTER XXXI.

CORKS.

CORKS are in many ways indispensable for laboratory purposes, and the stock should consist of all sizes; those for mounting apparatus being necessarily of the finest velvet kind, smooth and as free as possible from imperfections.

An excellent means of increasing the elasticity of corks is compression by a small apparatus, Fig. 530, sold for the purpose.

Fig. 530.



This treatment renders them capable of being fitted to apertures with great nicety and ease. For trimming them, as may be sometimes necessary, a sharp knife must be used. The cut surface can then be made perfectly smooth with a fine, flat file.

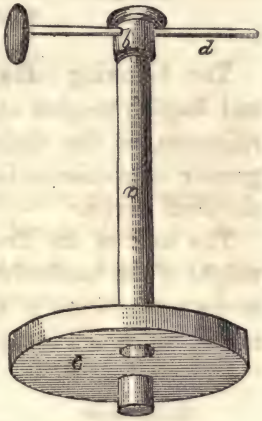
We have frequently made mention of the adaptation of tubes and other parts of apparatus by means of perforated corks. These perforations may be made with a hot metallic rod, and

Fig. 531.

afterwards enlarged with a rat-tail file; but a much smoother and neater hole can be made with a cork-borer, Fig. 531, which

is intended specially for this purpose. It consists of a series of brass tubes of uniform length, but varying from an eighth to one inch in diameter, and fitting one within the other. The sizes contained in such a series are equal to all the requirements of the laboratory, as holes of smaller or larger dimensions than the above extremes are seldom required. Each of the tubes is open below, but closed at the top with a cap *c*, Fig. 532, through which is a hole *b* for the passage of a stiff wire *d*, which serves both as a handle and as a punch for ejecting the cores from the tube after the perforation of the cork.

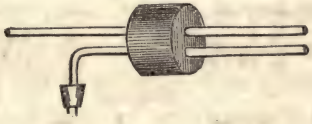
Fig. 532.



The drawing exhibits one of the tubes of the series already in operation, it being only necessary to bring its base upon a cork, and to effect the perforation by pressure upon the cap and a slight circular motion. The core or part of the cork removed, ascends into the barrel *a* of the tube, and must be ejected by the force of the punch *d*. As the tubes become dull on the edges, they may be sharpened upon a grindstone or with a fine file.

As a familiar illustration, we exhibit in Fig. 533 a cork thus treated, with tubes inserted in the perforations. Their convenience is shown in many of the arrangements of which we have given drawings.

Fig. 533.



When the corks are not of good quality, they may be rendered impermeable by coating their surfaces with *soft cement*.

India rubber corks have lately appeared in the market;—they are made by Goodyear, and answer admirably as cheap stoppers of bottles containing substances which are volatile, and which do not corrode the caoutchouc.

CHAPTER XXXII.

WEIGHTS AND MEASURES.

THE following tables of the corresponding values of French and English weights and measures will be found very useful for reference, as the decimal system of the French, owing to its greater convenience for calculations, is extensively adopted in chemical works.

The *unit* of the French weight is the *gramme*, which is the weight of the hundredth part of a cubic metre of distilled water, at the temperature of melting ice. Below are some comparative tables, which will serve to give every explanation.

		Grammes.		Troy Grains.
Milligramme	=	·001	=	·01543
Centigramme	=	·01	=	·15434
Decigramme	=	·1	=	1·5434

TROY WEIGHT.

English weights.			French weights.	
1 grain	= $\frac{1}{24}$ dwt.	=	0·06477	gramme.
1 pennyweight	= $\frac{1}{20}$th of an ounce	=	1·55456	gramme.
1 ounce	= $\frac{1}{12}$th of a lb. Troy	=	31·09130	grammes.
1 pound imperial		=	0·3730956	kilogramme.

AVOIRDUPOIS WEIGHT.

English.			French.	
1 drachm	= $\frac{1}{16}$th of an ounce	=	1·7712	gramme.
1 ounce	= $\frac{1}{16}$th of a pound	=	28·3384	grammes.
1 pound or 1 pound imperial		=	0·4534148	kilogramme.
1 cwt.	= 112 pounds	=	50·7824600	kilogrammes.
1 ton	= 20 cwt.	=	1015·6490000	kilogrammes.

		Grammes.		Troy grains.
Gramme	=	1	=	15·434
Decigramme	=	10	=	154·34
Hectogramme	=	100	=	1543·4
Kilogramme	=	1000	=	15434
Myriagramme	=	10000	=	154340

Or:

French.	English.
1 gramme = 15·438 grains troy	= 0·643 dwts. = 0·03216 oz. Troy.
1 kilogramme = 2·68027 lbs.	= 2 lbs. 8 oz. 3 dwts. 6 grs. Troy wt.
1 kilogramme = 2·20548 lbs.	= 2 lbs. 3 oz. 4$\frac{4}{5}$ drs. Avoirdupois.
1 myriagramme = 22·0485 lbs. Avoirdupois.	
1 quintal = 1 cwt. 3 qrs. 25 lbs.	

The unit of superficial measure is "the *are*, a surface of ten mètres each way, or 100 square mètres. The unit of measures of capacity is the *litre*, a vessel containing the cube of a tenth part of the mètre, and equivalent to 0·220097 parts of the British imperial gallon. The standard temperature is 32° F. All the divisions and multiples of the units are decimal."

MEASURES OF LENGTH.

Myriamètre	=	10,000 mètres.	Décimètre	=	0·1 mètres.
Kilomètre	=	1000 "	Centimètre	=	0·01 "
Hectomètre	=	100 "	Millimètre	=	0·001 "
Mètre	=	1 "			

MEASURES OF SURFACE.

Hectare	=	1000 sq. mètres.
Are	=	100 "
Centiare	=	1 "

MEASURES OF CAPACITY.

Kilolitre	=	1000 litres.	Litre	=	1 litre.
Hectolitre	=	100 "	Decilitre	=	0·1
Decalitre	=	10 "	Centilitre	=	0·01

The unit of solid measure is the *stere*, or cube of the mètre, equal to 35·31658 English cubic feet.

MEASURES OF LENGTH. LONG MEASURE.

English.		French.
1 inch or $\frac{1}{36}$ of a yard - - -	=	2·539954 centimètres.
1 foot equal = $\frac{1}{3}$ of a yard = 12 inches	=	3·0479449 decimètres.
1 yard = 3 feet - - - - -	=	0·91438348 mètre.
1 fathom = 2 yards - - -	=	1·82876696 "
1 pole or perch = $5\frac{1}{2}$ yards - -	=	5·02911000 mètres.
1 furlong = 220 yards - - -	=	201·16437000 "
1 mile, or 1760 yards - - -	=	1609·31490000 "

French.				English.
1 millimètre	=	0·039370		
1 centimètre	=	0·393708		
1 décimètre	=	3·937079		
1 mètre	=	39·37079	=	1·093633 yards.
1 décamètre	=	393·7079	=	10·936630 "
1 hectomètre	=	3937·079	=	109·366300 "
1 kilomètre	=	39370·79	=	4 furlongs, 213·633 yards.
1 myriamètre	=	393707·9	=	6 miles, 1 furlong, 156·288 yards.

French.	English.
1 toise = 6·3945 feet = 2·1315 yards = 76·735 inches.	
1 aune or ell = 3·893 feet = 46·79 English inches.	

SQUARE MEASURE.

English.	French.
1 square yard - - - - - - -	= 0·836097 mètre carré.
1 rod or pole = 30¼ sq. yards - - -	= 25·291939 mètres carrés.
1 rood = 1210 sq. yards - - - - -	= 10·116775 ares.
1 acre = 4840 sq. yards = 40·4671 ares = 0·404671 hectare.	
1 mètre carré = 1 centiare, - - -	= 1·196033 sq. yard.
1 are = 3·95 English poles - - -	= 0·98845 rood.
1 hectare = 2 acres, 1 rood, 5 perches, -	= 2·473614 acres.

MEASURES FOR LIQUIDS.

English.		French.
1 pint or ⅛th of a gallon	=	0·567932 litre.
1 quart or ¼th of a gallon	=	1·135864 litres.
1 imperial gallon	=	4·5434579 "

DRY MEASURE.

English.			French.
1 peck	=	2 gallons =	9·0869159 litres.
1 bushel	=	8 " =	36·347664 "
1 sack	=	3 bushels =	1·09043 hectolitre.
1 quarter	=	8 " =	2·907813 hectolitres.
1 chaldron	=	12 sacks =	13·08516 "

French.	English.
1 litre = 1·760773 pints = ·8803865 qts. =	·2200966 gallons.
1 decilitre - - - - - -	= 2·2009667 "
1 hectolitre - - - - - -	= 22·0096670 "

As a greater convenience for common purposes, the French denominations were, in 1812, arranged as follows:

1 toise or 6 feet = 2 mètres	= 6·5618334	English feet.
1 foot or 12 inches = ½ mètre	= 1·0936389	" foot.
1 inch or 12 lines - -	= 1·0936389	" inch.
1 line - - - - -	= 0·0911365	" "

1 aune or ell = 1 ½ mètre = 3 937 English feet:—Or,
1 aune - - - - = 47·244 " inches.

1 bushel = ⅛ hectolitre = 762·85 cubic inches.

1 old Paris foot	= 1·066	English foot.
1 old Paris inch	= 1·066	" inch.
1 old line	= 0·0888	" "

The metre, the square metre, and the cubic metre, are the radical standards of the three measures; for there are only three,

as solidity and capacity, differently named and used, are the same in reality. From these radical denominations, namely, the *metre* of the lineal measure, the *are* of the superficial measure, the *litre* of measured capacity, and the *stere* of solid or cubic admeasurement, the larger ones are procured by multiplying by ten, and the lower ones by dividing by the same. Thus,

Deca,	prefixed,	means	10	times.
Hecto,	"	"	100	"
Kilo,	"	"	1000	"
Myria,	"	"	10,000	"

The number is understood to multiply the surface of the solid and not its side; thus, one decare is ten ares, not a square of ten times the side of an are, and so of the others.

The denominations below the radical ones are expressed by a sort of Latin prefix: thus,

Deci is one-tenth.
Centi is one-hundredth.
Milli is one-thousandth.

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